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DEVELOPMENT OF THE ALUMINUM INDUSTRY OF THE USSR

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DEVELOPMENT OF THE ALUMINUM INDUSTRY OF THE USSR

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I.M. Gratserahteyn

Chapter II

Principal Stages in the Development of the Soviet Aluminum Industry

The Aluminum Industry During the Great Patriotic War

As a result of the treacherous attack of Fascist Germany on the Soviet Union, the aluminum industry suffered severe losses at the beginning of the war.

In the autumn of 1941 the Volkhov and Dneprovsk Aluminum Plants, the Tikhvin Aluminum Oxide Plant and the Tikhvin Bauxite Mines were put out of operation; in this connection the aluminum industry lost a large part of its productive capacity, including: bauxite 35%, alumina 60%, aluminum 55% and silumin 100%.

The Party and the Soviet government faced the serious task of recovering the lost potential in the shortest possible time and of constantly meeting the needs of the front for aluminum and aluminum alloys.

During the second half of 1941 a start was made on moving establishments of the aluminum industry toward the east, a hitherto unheard of feat in the history of world industry.

The equipment of the Dneprovsk, Volkhov and Tikhvin plants and of the Tikhvin bauxite mines was dismounted and shipped off. On the basis of this equipment the aluminum industry installations under construction in the eastern areas were put into production at an accelerated rate.

It was necessary to erect new shops, install and put into production the equipment at the aluminum and alumina plants under extremely difficult conditions and with a great shortage of material and labor.

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The operation of the aluminum establishments during the war period was complicated not only by a shortage of laborers but of engineering and technical personnel.

The demand for labor, complicated by the drafting of a portion of the qualified workers into the Soviet Army, was met by young people from the factory vocational and trade schools and through mobilization of the public. During the three years 1943-1945 establishments of the aluminum industry trained 33,000 workers, including 13,000 given new training and 20,000 giving further training.

As a result of the Party and government's constant interest in the development of the aluminum industry and thanks to the self-sacrificing labor of workers and engineering and technical personnel the production capacity of the aluminum industry increased from year to year, despite the temporary occupation of important economic regions of the USSR by the Fascist invaders.

During the war there were major changes in the supply of ore to the aluminum industry (Fig.1).

Despite the termination of bauxite production at the Tikhvin mines during the last half of 1941 the overall capacity was rapidly regained by expanding production from the Northern Ural and Kamensk mines.

Exploitation of the Northern Ural mines started in 1934.

During the Great Patriotic War the Northern Ural Bauxite Mines faced the responsible task of providing bauxites for the expanding capacity of the alumina plants and of meeting the requirements of the iron and steel industry, and the abrasive, cement and other industries.

In connection with the evacuation of the equipment of the Tikhvin bauxite mines and the relocation of aluminum plants in the Urals and in Siberia, the Northern Ural Bauxite Mines became the main source of raw materials for the aluminum industry. The increase in bauxite production was accompanied by a reduction in open-pit and an increase in underground mining (Table 4).

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TABLE 4

RATION BETWEEN OPEN-PIT AND UNDERGROUND BAUXITE MINING AT
NORTHERN URAL BAUXITE MINES DURING THE WAR YEARS

Year	Production %	
	open-pit	underground
1940	76.5	23.5
1941	75.6	24.4
1942	73.3	26.7
1943	71.5	28.5
1944	56.9	43.1
1945	50.8	49.2

At present reserves suitable for open-pit working have been almost used up and underground mining is the principal practice at mines.

The Kamensk Bauxite Mines were put into production in 1939. Administratively they became a part of the Ural Aluminum Plant with the status of an independent mining unit consisting of three bauxite mines (Sokolovskoye, Bagryak and Pirogovskoye) and the Bagryak lime quarry.

The principal operating mine since the start of the exploitation of the Kamensk Bauxite Mines has been the Sokolovskoye mine.

The Tikhvin bauxite mines came into operation in 1929. Until the war they were the principal supplier of bauxite to the aluminum industry.

Besides the aluminum industry enterprises in the abrasives, iron and other industries used bauxites from these mines.

The maximum production of bauxite at the Tikhvin mines was reached in 1940 when it was 50% of the total production and was twice that of production at the Northern Ural mines.

The fourth five-year plan for the restoration and expansion of the national economy, 1946-1950, aimed at restoring the Tikhvin bauxite mines to a capacity suitable for fully supplying the operation of the Tikhvin Alumina Plant and meeting the bauxite requirements of the abrasives industry of the northwestern provinces.

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Bauxite production at the Southern Ural Bauxite Mines started in 1936.

Bauxites from the Southern Ural mines were shipped to the Dneprovsk Aluminum Plant, units of the abrasives industry, and other customers.

The great expansion of the Ural Aluminum Plant made it the principal producer of alumina and aluminum during the Great Patriotic War. The output of aluminum at the Ural Aluminum Plant increased rapidly during the war and after. The output of alumina increased still more rapidly. By the beginning of 1942 it had exceeded the prewar level by 50% and by 1946 by 200%.

During the war there were considerable difficulties at the Ural Aluminum Plant due to the irregular and limited supply of electric power, to the shortage in qualified labor, material for repairs (cathode rods, hearthblocks, cast iron, etc.).

In the attempt to achieve new production levels all this led to a deterioration in some technical and economic aspects of the operation of the plant (reduction in the production of first grades, increase in the consumption of material and electric power per unit). The successful operation of electrolytic shops depends on a number of factors of which the principal are the electric power supply for the cells, the number of cells in operation and their condition, the composition of the electrolyte, and the type of maintenance given the cells.

The power supply during the war years was marked by great fluctuations both from the daily and from the annual point of view. Fluctuations in amperage during a 24-hour period hampered the smooth operation of the cells and reduced the gross production and quality of the metal. Great limitations made it necessary to shut out some of the operating cells which reduced the output of metal and led to losses in electric power.

The higher load of the summer months brought on a disturbance in the normal course of the electrolytic process. Fluctuations in the electric power supply during the 24-hour period caused marked wear in the cells and reduced considerably their normal operating life.

Great difficulties in the operation of the alumina shops of the Ural Aluminum Plant were occasioned by the processing of the Northern Ural bauxites which have a higher calcite content.

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Thanks to the unselfish work of factory personnel the difficulties of the war period were overcome and a high output of metal was assured to meet the needs of the front. In 1944 the Ural Aluminum Plant was awarded the Order of Lenin.

In 1943 the alumina division of the Bogoslovskoye Aluminum Plant in the Northern Urals was put into production. The plant was located near resources of raw materials and power.

The electrolytic division of the Bogoslovskoye plant went into operation the day of our victory over Germany, May 9, 1945.

In 1943 the Stalin Aluminum Plant started operation. It produces metallic aluminum from alumina brought from elsewhere. The location of the plant in Western Siberia was determined by nearness to the power resources of Kemorovo coal.

Western Siberia is one of the richest fuel sources of the area. Here is located the Kuznetsk Coal Basin, the richest in the world.

The size of the power resources of Western Siberia and the low cost of coal production created favorable conditions for the development in the Kuznetsk Basin area of an aluminum industry utilizing considerable power.

The construction of the Stalin Aluminum Plant was started before the war.

The difficulties of the war years and the necessity for rapidly extending the capacity of the aluminum industry were reflected in the condition of the equipment of the electrolytic division of this plant. The cells installed have a simplified design (oval shells without gas exhaust). There were no transportation facilities for all movement within the shop.

All these circumstances complicated the work of the plant to a considerable degree.

The average current was below that foreseen by the plan and this reduced the productivity of the cells.

Output based on current and energy was small. The principal causes of low ouput were the irregularity of the power supply and the failure to supply sufficient electricity, defects in cell design and installation, and shortage of qualified personnel for the electrolytic processes.

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The shortcomings in the design and installation of the cells was revealed as early as 1943. The shells of the cells were not sufficiently strong. During operation cracks appeared along the seams of the shells and they had to be strengthened.

As the result of failure to anchor the cells strongly enough to the foundations the cells underwent widespread tilting which made their operation difficult and reduced their effective life.

The oval shells made from 6 - 8mm iron were intended for 1.5 - 2 years of service. In fact they were in operation without replacement for 3 years because of the lack of shells to replace those which were worn out.

The consumption of raw material and electric power was relatively high.

Despite difficulties in mastering production during the war years the Stalin Aluminum Plant was a supplementary source of aluminum for meeting the needs of the front line.

Along with an increase in quantity the aluminum industry of the USSR also achieved marked success during the Great Patriotic War in improving equipment, in rendering production processes more efficient and in improving general operating factors at aluminum plants. During the war years there were great changes related to the introduction of the Bayer method, the most modern method for producing alumina. While the Bayer method accounted for only 42% of the total alumina production in 1941, up to 94% of the total alumina was produced by this method in 1945 (Table 5).

TABLE 5

ALUMINA PRODUCTION METHODS DURING THE WAR

Method	1941 Plant	%	1945 Plant	%
Dry sintering	Volkhov Alum.	14		
Wet " "	Tikhvin Alum.	11	Bogoslovskoye Aluminum	6
Electrothermal	Dneprovsk Alum.	33		
Bayer	Ural Aluminum	42	Ural Aluminum	94
Total		100		100

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At the Bogoslovskoye Plant the sintering furnaces were operated on powdered coal instead of fuel oil for the first time in the world.

At the Ural Plant the Bayer method was adapted to processing bauxites with a high calcite content. For this purpose the plant built a special causticizing installation which converted into caustic soda the excess soda formed from the calcites which are brought in with the Northern Ural bauxites.

Technical changes in the production of aluminum are characterized by the development and introduction of improved large-capacity electrolytic cells with continous anodes designed by Soviet scientists.

Before the war small cells with baked anodes were used in the electrolytic sections of the Vokhov and Dnepr Aluminum Plants.

The presence of a large number of anodes in the bath complicated regulation, did not guarantee equal distance between poles throughout the entire cell and caused local overheating. The use of baked anodes in the cells necessitated the construction of electrode plants and the installation of large anode presses with pumping apparatus and the construction of expensive furnaces with gas generator stations.

For cells with periodic baked anodes it was impossible to design gas exhaust apparatus and to mechanize the hardest processes.

For this reason the introduction of a large mechanically operated cell with a continuous self-baking anode marked a raise in the technological level of the aluminum industry of the USSR.

In Table 6 we have data which describe technical changes in the production of aluminum.

TABLE 6

TYPES OF ELECTROLYTIC CELLS IN PERCENTAGE OF TOTAL

Type	1941	1945
Small with prebaked anodes	54	
Large with continuous anodes	46	100
Total	100	100

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The conversion from cells with prebaked anodes to cells with self-baking anodes underwent an intermediate stage, the use of cells with three self-baking anodes in the first series at the Ural Aluminum Plant which went into operation before the war. These three-anode cells gave lower production and used more electricity than single-anode cells, were hard to maintain and did not provide for the exhaust of fluorine gases which made for bad working conditions. These cells operated in the first series during the entire war period.

During the Great Patriotic War the production of silicon and silumin was organized and put into operation. In 1944 the production of silumin of grades 0 and 1 reached 97%. The demands of the aviation and tank industries for silumin were completely satisfied by Russian production.

The production of pyrotechnic mixtures was also organized and put into operation.

Technical progress in the production of fluorine salts is shown by the adoption of a continuous method for the production of cryolite at the Polevskoy Cryolite Plant which doubled the production capacity of the apparatus and improved working conditions, by improving the fluorspar flotation system, and by developing a process for the production of hydrofluoric acid in furnaces with internal heating.

As a result of the heroic efforts of the Soviet Union the wartime objectives in the development of the aluminum industry were successfully met.

On the basis of the modern aluminum industry developed during the five-year plans, the erection of plants in the eastern areas of the country (which had started before the war), the rapid restoration of the evacuated plants and the construction of new ones, the aluminum industry during the Great Patriotic War increased its production capacity, expanded its source of raw material, raised the technical level of aluminum and alumina production and supplied the war industries with aluminum.

The Soviet state during the war summoned up sufficient strength and material not only to reestablish the evacuated plants but to accelerate the construction of new establishments in the aluminum industry.

4. The Aluminum Industry During the Postwar Period

The fourth five-year plan for the reconstruction and expansion of the Soviet national economy for the period 1946-1950 aimed at the

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further development of all branches of the nonferrous metal industry. The plan proposed rapid rates of growth in the production of nonferrous and rare metals in order to satisfy the growing demands of the national economy.

The grandiose objectives of the fourth five-year plan required still further and more accelerated technical progress in production, the over-all introduction of the latest equipment and the mechanization of operations requiring considerable labor, a high level of production, maximum economy and efficient organization.

The fourth five-year plan, on the basis of improving the operation of existing enterprises, the construction of new plants and the reconstruction of plants in areas which had been under occupation, planned to turn out twice as much aluminum as in 1945.

In order to meet this aim the law governing the five-year plan provided for the restoration of the Tikhvin bauxite mines, the Dneprovsk and Volkhov Aluminum Plants and the Tikhvin Alumina Plant, for increasing the capacity of the Northern Ural Bauxite Mines, the Bogoslovskoye and Stalin Aluminum Plants and the construction of a number of new enterprises. Actually aluminum production in 1950 was 1.8 times that of 1945. There was a marked increase in aluminum production at the Ural, Stalin, Bogoslovskoye and Volkhov Aluminum Plants.

During the fourth five-year plan the Volkhov and Dneprovsk Aluminum Plants were reconstructed. Aluminum production started at the Volkhov plant in 1946. The Electrolytic section of this plant had suffered comparatively little and for this reason it was restored to the prewar system of cells with baked anodes and the prewar level of aluminum production was surpassed as early as 1948. As a result of improving the technological system and the general development of modern working methods the production capacity of the electrolytic section continued to increase in 1950 and exceeded what had been planned. The Volkhov plant reached the highest output per current consumption in 1950 in the aluminum industry. The alumina section of the Volkhov plant was restored in 1949. During the period 1949-1950 the alumina section of the Volkhov plant adopted a new system for processing nephelines with the simultaneous production of cement, potash and soda. The output of alumina did not satisfy the demands of the electrolytic section which imported some alumina from the Ural plants.

The Dneprovsk Aluminum Plant went back into production in 1949 with its electrolytic section. The restoration of the alumina section to its prewar state was admitted to be impractical in view of the high

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production cost of alumina obtained by the Kuznetsov-Zhukovskiy method and the absence of known industrial resources of local alumina raw material. For this reason it was planned to reestablish the plant on the basis of processing imported bauxites with the possible subsequent conversion of the plant to Russian raw material.

The electrolytic section of the Dneprovsk Aluminum Plant was rebuilt according to a new production system (electrolytic cells with one self-baking anode).

The starting period dragged out because of poor cell installation and the instability of the lining blocks as well as the irregularity of the power supply, the lack of a well-developed optimal system for type of cell decided on and the lack of reserve capacity at the mercury conversion substation.

The restoration of the electrolytic section of this plant was not completed until 1951.

During the postwar five-year period the capacity of the Stalin and Bogoslovskoye Aluminum Plants was expanded and the Kanaker Aluminum Plant was put into operation in 1950. The Kandalaksha Aluminum Plant was made ready for operation and the Sumgait Aluminum Plant was built.

During the period 1946-1950 cells with rectangular shells at the Ural and Stalin Aluminum Plants were replaced by the lighter-type cells with oval shells as planned. In addition, the three-anode cells at the Ural plant which had provided a low production level and had undergone considerable wear were replaced by single-anode cells. At all the plants the equipment was improved, the ventilation systems were repaired and better working conditions were provided. Work was done on making production processes automatic in the alumina sections and on providing them with control and measuring apparatus.

At the Bogoslovskoye plant an alumina section was built to operate on the Bayer system with simultaneous reconstruction of the section operating on the sintering system in order to convert the entire production of alumina in the plant to a combined Bayer-sintering system.

In the electrolytic sections of aluminum plants there was increased use of pneumatic hammers for breaking the electrolyte crust in the cells and of devices for pulling the pins. The electrolyzers were furnished with louvered covers and pipes for the removal of harmful exhaust gases into the upper layers of the atmosphere; the metal was

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tapped from the baths by means of a siphon and vacuum ladle; the level of metal following tapping was raised; the casting of ingots in molds was replaced by semicontinuous casting; a whole set of operations was carried out to reduce voltage losses at anode and cathode contacts; calcium fluoride was added to the electrolyte; all this led to an improvement in technical and economic factors relating to the operation of the electrolytic sections.

At the Ural plant work was done on making industrial use of processes for the continuous leaching of bauxites in a series of autoclaves and tests were run on new designs of electrolytic cells with top current lead and increased capacity.

A major achievement of the aluminum industry during the period 1949-1950 was the production of high-purity aluminum on an industrial scale.

The raw material supply of the aluminum industry was considerably expanded. There was an increase in the known reserves of raw material for the aluminum industry. The production of bauxites at the Northern Ural Bauxite Mine in 1950 was 1.34 times that of 1945.

A number of major shafts were started at the Northern Ural Bauxite Mine in order to expand underground extraction of bauxites.

Most of the operations in extraction were mechanized. The Tikhvin mines were restored and work was started at the Southern Ural Bauxite Mines. Commercial use was made of nepheline concentrates at the Kirovo Concentration Plant. The great expansion in the supply of raw materials in the USSR was due to the use not only of bauxites but nephelines which made possible the over-all utilization of raw material with the production of a number of nationally important products and the creation of an aluminum industry in a number of new areas in the country. Aluminum production was to increase 2.6 times during the fifth five-year plan but did in fact increase 2.77 times.

Along with the expansion of production at existing plants, the new Kandalaksha, Nadvoytsy and Sungait Aluminum Plants were built and put into operation. Considerable work was done on intensifying the electrolytic process at existing plants by increasing current in the electrolytic series and by adopting modern techniques with the use of acid electrolytes and increasing current density with current stabilization in the series.

Increasing current density became the basis for development and improvement in the technology of electrolysis. During the period in

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question current density in the electrolysers of all the aluminum plants increased constantly. For instance anode current density increased 16% at the Ural and Kanaker Aluminum Plants, 20% at the Dneprovsk Plant, and at the Volkhov plant anode density in 1956 was 27% higher than in 1947.

An electrolyte formula enriched with aluminum fluoride was developed and adopted. By the end of 1955 the cryolite proportion of the electrolytes in the aluminum plants dropped to 2.2 - 2.5 as compared with 2.8 - 3.0 in 1951.

There was also a considerable reduction in the number of anode effects.

The Volkhov Aluminum Plant was able to reach and maintain at length a small number of anode effects of the order of 0.2 - 0.3 per 24 hours in multianode electrolysers. The frequency of anode effects at the Kanaker plant in 1956 was approximately 0.2 per 24 hours.

By intensifying production the capacity of the aluminum plants was 20% greater at the end of the fourth five-year plan than at the beginning.

Electrolyser capacity continued to grow. In the new series the capacity of the electrolysers increased to 80,000 amperes.

Work was done on modernizing equipment. In particular, the Stalin Aluminum Plant reconstructed the different electrolysis buildings with the installation of more powerful electrolytic cells which assured an increase in the capacity of the electrolytic sections and a great improvement in working conditions.

Along with this reconstruction in 1949 new series of electrolytic baths were completed in 1951-1953.

The principal trends in the improvement of the electrolytic process during the fifth five-year plan at the Stalin Aluminum Plant, in addition to increasing current in the electrolysers, were raising the metal level, reducing the cryolite fraction of the electrolyte, reducing fluctuations in current, reducing the frequency of explosions and strains in all current-conducting parts of the electrolysers.

At the Volkhov Aluminum Plant the production of high-purity aluminum was put into effect on a commercial scale, a powerful electrolyser for refining aluminum was developed and built in 1955-1956. A number of difficult and labor-consuming operations were

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also mechanized at the aluminum plants (drawing and driving pins in the anodes of electrolytic baths, breaking through the top crust and cleaning off the side crust on the walls, switching contacts in the pin-bar area, cleaning the contact surface of the copper tips of the anode lifts, rubbing the surface of the side carbon blocks, pneumatic raising of the louvered covers) and work was being done on automatic control of the aluminum electrolytic process.

In the fifth five-year plan much research was also done on testing and developing new types of aluminum electrolyzers, finding ways for further intensifying existing series and increasing the service life of the electrolyzer bottoms, and studying processes which take place at the anode and cathode in aluminum cells.

In connection with the introduction of a number of technical measures during the fifth five-year plan there was an 182% increase in the production of alumina with marked improvement in all technical and economical factors. The extraction of alumina from bauxites increased 7% at the Ural plant and 13% at the Bogoslovskoye, for example.

At the Bogoslovskoye Aluminum Plant a new system for producing alumina by the Bayer-sintering method with the most modern equipment was introduced (nonclogging crushers, apparatus for continuous leaching, multistage thickeners, etc.).

After the reconstruction of the Tikhvin Alumina Plant in 1952 a system for processing low-grade bauxites for alumina was introduced which was superior to that used before the war.

At the Volkhov Aluminum Plant a method was adopted for the over-all processing of nepheline raw material for alumina, soda products and cement which is very important for the further development of the over-all processing of nephelines in the different areas of our nation. For this work a group of factory workers, scientists and researchers was awarded the Lenin Prize in 1957.

In 1955, following reconstruction, the alumina section of the Dneprovsk Aluminum Plant started operation under an improved system.

At the Ural Aluminum Plant a method was introduced for the continuous leaching of bauxites in autoclaves at high pressure which made it possible to increase the production of the autoclaves 2.5 times, reduce the consumption of fresh steam by 30% and greatly increase the extraction of alumina from bauxites.

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The single-stage Dorr apparatus for thickening and washing red slurry was modernized with the installation of an additional stage in each apparatus. This made it possible to increase the production capacity of slurry thickeners 1.7 times and the capacity of washers 1.5 times with the same space and personnel involved. Control filtration of the aluminate solution was done in one of the alumina sections on Kelly leaf filters using a paper mass for the filtering material instead of the previously employed Abraham filter presses (with cotton cloth).

Many other improvements were also made in alumina production. For instance, in the evaporation of mother liquors a two-stage method was introduced for separating soda from the working solutions, and a system for separating harmful organic admixtures from the solutions was adopted. In calcination the lining of the rotary furnaces was changed from smooth to honeycomb-ribbed; the heat of the alumina coming from the furnace was utilized for additional heating of the steam entering the injector for atomizing the fuel oil; the gas cleaning system was altered.

All these measures introduced in the calcination of alumina made it possible to increase furnace production by 40% and reduce the unit consumption of fuel oil by 20%.

A new system was developed (reduction method) for the over-all processing of aluminite for alumina, sulfuric acid and fertilizers. Work was done on automatizing the separate phases in alumina production (bauxite grinding, continuous leaching, calcination furnaces, etc.).

The Party and the government have paid particular attention to the development of a source of raw material for the aluminum industry. Bauxite production increased 2.33 times during the fifth five-year plan.

At the Northern Ural Bauxite Mines major new shafts were put into operation for the underground extraction of bauxites, not only basic but auxiliary operations were mechanized, work was begun on automatic control for shaft, pumping and ventilation installations, and work was done on improving the processing system, etc.

Of considerable importance in increasing bauxite production at the Northern Ural Bauxite Mines was the introduction of high-speed drifting which greatly increased the average speed of mining working operations.

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In 1947 upon the initiative of innovator drifters at the Northern Ural Bauxite Mines an All-Union Socialist Competitition for Tunneling Brigades in high-speed mining operations.

From year to year the Northern Ural miners have stepped up the tempo in opening drifts, the total number of which exceeded 700. While in 1948 and 1949 there were 11 high-speed drift openings per month, in 1950 there were 27, in 1951 43, in 1952 72, in 1953 89, in 1954 119 and in 1956 125. The maximal rate of opening horizontal workings (drifts) reached 203.4 linear meters in 1948, 254 in 1949, 268.6 in 1950, and 302 linear meters in 1956.

There was a marked increase in the monthly high-speed opening of inclined workings: 75.5 linear meters in 1947, 105.3 in 1951, 134 in 1952, 133.2 in 1953, and 225.8 linear meters in 1956.

During these years a total of over 125 kilometers of underground mine room was opened, approximately one-half of them by high-speed methods. Such speeds enabled the Northern Ural Bauxite Mines to obtain ores where necessary at great depths where it was impractical to use open-pit methods, although open-pit methods were also used at the mines.

The amount of ore extracted and the amount of rock waste removed at the Northern Ural Bauxite Mines in 1955 was twice that of 1950.

The restoration of the Tikhvin Bauxite Mines was completed in 1948. In 1949-1954 new mechanized quarries were opened.

At present the Tikhvin bauxite mines are a major mechanized mining operation provided with modern equipment for open-pit mining.

The removal of overburden and the loading of the bauxites is done by excavators while transportation is in 60-ton dump cars. At these mines an open-pit system has been adopted as developed by the State Planning Institute for the Nickel Industry in which opening is done without transportation by powerful ESh-4/40 walking excavators.

During the fifth five-year plan the removal of overburden to obtain bauxites at the Tikhvin bauxite mines increased by more than 4.5 times and is illustrated by the data in Table 7.

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TABLE 7

INCREASE IN THE REMOVAL OF OVERBURDEN AT THE TIKHVIN BAUXITE MINES FOR 1950-1956 IN THOUSANDS OF CUBIC METERS.

Year	Overburden removal	
	Total	By the nontransport system
1950	311.1	--
1951	545.1	--
1952	672.6	132.2
1953	957.6	438.0
1954	1193.7	998.6
1955	1400.1	996.2
1956	1838.0	1212.6

CHAPTER III

LABOR PRODUCTIVITY IN THE ALUMINUM INDUSTRY OF THE USSR

1. Significance of the Growth in Labor Productivity

The increase in labor productivity in the aluminum industry is an important factor in the increase in the productivity of communal labor in the Soviet Union since aluminum plays a most important role in the expansion of the leading branches of industry and in the improvement of their equipment. Further technical progress in a number of branches of industry (transportation, machinery manufacture, electrical, construction, etc.) is connected with the extensive use of aluminum and its alloys.

An increase in labor productivity in the aluminum industry leads to a reduction in the amount of human labor expended per unit of the metal produced which will result in a reduction in the amount of communal labor utilized in all branches which employ aluminum.

During the prewar period the level of labor productivity in the aluminum industry was relatively low. Because of the lack of known high-grade bauxite deposits the aluminum industry was obliged to utilize during its first years the Tikhvin bauxites with their high silicon content and they had to be processed into alumina by sintering and not by the improved Bayer method. Electrolytic production

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utilized primarily cells with baked electrodes which are less productive than cells with self-baking anodes.

Not long before the war alumina plants were operating partially on Northern Ural bauxites.

During the Patriotic War the aluminum industry converted completely to the processing of high-grade bauxites from the Northern Ural mines and to the predominant use of the Bayer system in the production of alumina. At aluminum plants the principal type of electrolyzer became the more productive cells with a single self-baking anode. By this time the aluminum industry already had at its disposal experienced workers and engineering and technical personnel who were used to staff the new aluminum plants in the Urals and Western Siberia.

In connection with the difficulties of the war period there was an interruption in the normal power supply to enterprises, in the provision of basic and auxiliary materials and spare parts and there was a lowering of the level of labor productivity, particularly during the first years of the war.

During the initial period of the war the influx of a large mass of workers, including women and young people not previously employed in industry, naturally caused a drop in labor productivity at aluminum plants. A certain period of time was required in order for the new personnel to master production techniques and become qualified workers. Thanks to patriotic labor efforts the workers acquired working habits and became skilled personnel very rapidly and by the end of the war labor productivity substantially exceeded the prewar level.

The postwar period was a period of reconstructing enterprises destroyed by the war and of further expanding the aluminum industry; it is characterized by a great increase in labor productivity. During the fourth five-year plan (1946-1950) labor productivity increased 46%, or by 48.6% as compared with 1940. As a result of the tempo of growth, labor productivity in the aluminum industry exceeded the average for industry as a whole by 37%.

Improvement in technological processes, the reconstruction of electrolytic plants at operating aluminum plants, the mechanization of the more difficult operations, the acquisition of greater skill by the workers, the development of modern forms and methods of work, and the improved material welfare of the workers served as a basis for a further increase in labor productivity.

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In the fifth five-year plan (1951-1955) the tempo of growth of labor productivity in the aluminum industry was still more marked.

In 1955 as compared with 1950 the gross production per worker increased 64.1% with an average index of increase in industry as a whole of 44%.

The production of market aluminum per regular employee in 1955 was 74.6% greater than that in 1950.

Labor productivity in 1956, the first year of the sixth five-year plan, increased over 1955 by 11.8% at the Ural plant, by 10.2% at the Stalin plant, by 9.1% at the Kandalaksha plant and by 13.6% at the Kanaker plant.

The achievements made in the growth of labor productivity did not exhaust all possibilities in this area. The revelation of further potentials for the growth of labor productivity requires a detailed study of isolated factors, an analysis of which requires consideration of data connected with the introduction of new equipment, the use of machinery and automatic control in production processes, the conditions surrounding the extraction of raw material and the organization of labor and production.

2. Factors in the Increase in Labor Productivity in the Aluminum Industry Connected with the Introduction of New Modern Equipment

Where production methods are identical, great importance will be attached to the selection of the largest high-production apparatus which will provide the maximum degree of mechanization and the possibility for automatic control, which is connected with the lesser number of operating personnel (for example, the use of continuous leaching of bauxites, the replacement of single-stage thickeners by multistage, two-stage crushing of bauxites in different types of crushers replaced by crushing in powerful crushers, substitution of apparatus with simultaneous soda crystallization for ordinary evaporators).

In planning new plants and reconstructing old ones it is necessary to aim at more powerful units of improved design in the different areas of alumina production instead of the installation of numerous apparatus of low production capacity.

The influence of the design of apparatus on labor productivity can be illustrated by the electrolysis of cryolite-alumina melts.

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The design of electrolytic cells is an important factor in labor productivity in aluminum plants, determining essentially the level of metal output per cell per 24-hours.

This factor under a normal power cycle is likewise determined by the continuity of supply of raw material and excellent maintenance of equipment.

In addition to technological advantages which assure a higher output per cell per day, single-anode cells are simpler to maintain than multianode cells and require less expenditure of labor.

Progress in the electrolytic process leads to an increase in the capacity of the cells. The design of cells for operation on higher current assures increased output per cell-day and greater labor productivity.

In the history of the development of the Soviet aluminum industry we observe a progressive tendency toward increasing the capacity of the electrolyzers by increasing the current with corresponding changes in cell design.

Work has been done in the USSR on finding the most productive designs for electrolyzers with current lead in to the anodes on the top, a reduction in the amount of electric power consumed and an increase in metal output per cell-day. Through more complete mechanization of processes of charging the alumina, rearrangement of the pins and the elimination of the operation of servicing the contacts, the number of workers engaged in maintaining cells with a top current lead-in is being markedly reduced.

At present the current in the different series of electrolyzers with continuous self-baking anodes has reached 80,000 amperes while at the new aluminum plants under construction the plan calls for the installation of powerful electrolyzers operating on 130,000 amperes and higher with top current lead-in, and the mechanization and automatic control of the electrical portion of cell operation.

At aluminum plants considerable work is being done on introducing new equipment and modern techniques. For instance, at the Stalin Aluminum Plant reconstruction of electrolytic series 1 to 3 was finished with the installation of more powerful cells; the cryolite portion of the electrolytes was reduced and automatic control of current stabilization in the series was set up; the frequency of anode effects was reduced; pneumatic machinery was installed for cleaning contact surfaces; all cells have been converted to tapered

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pin-bar contact and a series of organizational and technical measures have been carried out aimed at increasing the technical level of production.

In conjunction with the All-Union Aluminum and Magnesium Institute production tests are being made of experimental electrolyzers with top current lead-in, and of an anode compound made of coke from petroleum with a high sulfur content; a method is being adopted for determining output per current unit by using radioisotopes; a study is being made of the circulation of the metal and electrolyte in the cells as effected by a magnetic field; a test is being made of longer pins for cells with lateral current lead-in and a number of other projects are under way which are of great importance for improving all aluminum production factors.

A great role in the increase in labor productivity in alumina production is being played by the further improvement of apparatus at alumina plants with relation to increasing the productivity of the basic units, to providing maximum mechanization and automatic control of processes and conversion to continuous processes.

In particular, there should be greater speed in introducing into alumina production the new types of high-production apparatus: tube ball mills 3.2 meters in diameter and 15 meters long for wet grinding of the charge; sintering furnaces 4-5.5 meters in diameter and 100 meters long for the bauxite mixture; calcination furnaces 4.5 meters in diameter and 100 meters long; a five-chamber thickener 20 meters in diameter; an 1800 cubic meter decomposer with air stirring; a tube leacher for leaching aluminate cake chunks.

Of great promise are also the use of hydrocyclones in classifying or settling apparatus in a number of process in alumina production, furnaces with fluidized beds (calcination of aluminum hydroxide in a fluidized bed), etc.

At the Ural Aluminum Plant tests have been made of hydrocyclones in different areas of alumina production: bauxite grinding, thickening the red slurry, classification and thickening of hydrate pulp and thickening of white slurry, obtained from caustication of the carbonate soda. In the bauxite grinding units where the hydrocyclones have been put into production there has been an improvement in grinding and a reduction in power consumption. Tests under production conditions have also been made of a pilot refrigeration plant for chilling the alumina in a "fluidized bed." The full possibility of chilling the alumina in a "fluidized bed" has been established.

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As a result of introducing new and improved equipment, the mechanization and automatic control of production processes, improvement in production and labor organization, multiple-unit maintenance (brigades have been converted to maintain 10 or more cells) the number of workers has been reduced while there has been an increase in production. In particular, there was a 3.7% reduction in the number of workers at the Ural plant from 1955 to 1956, at the Stalin Plant a 14.3% reduction, at Kandalaksha 8.7% and at Kanaker 10.9%.

3. Labor Productivity at the Northern Ural Bauxite Mines

The basis for the increase in labor productivity at the Northern Ural Bauxite Mines was the mechanization of production processes, the increase in supplying labor with power equipment, improvement in tunneling and mining operations and in the organization of labor. During the fifth five-year plan the coefficient of power equipment in use more than doubled.

Simultaneously with the improvement in the system of top slicing work was done on finding a more efficient operating system. Since 1954 operation has been started on the system of open stoping with bench excavation and timbering with poles, as proposed by Engineer N. A. Alekseyevskiy.

Recently the Northern Ural Bauxite Mines have seen the introduction of a room variant in extracting ore with pole timbering and subsequent working of the pillars between rooms by a system of top slicing. The use of this system has given good results. The stope brigade under Comrade Roshkov at mine No.2 of the second Northern Mine increased extraction of ore from the block up to 240 tons which corresponds to the production of ore at a mine with four blocks. The production per stopeman per shift is 6.3 cubic meters of ore which is double that which had been planned.

With this system the cost of extraction is much lower than with top slicing and even with longwall mining of the blocks using pole timbering, for when the lower layers are worked it is not necessary to timber the room.

The pillars between the rooms which are worked by top slicing after the chambers have been caved in, fulfill the role of roof supports reinforced by poles.

The new system also has the advantage of excluding irretrievable losses of ore which is inevitable in other extraction systems.

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Labor productivity of miners increased 2.2 times from 1949 to 1956.

The lowest level of labor productivity during the fourth five-year plan was 1946 when the proportion of underground work increased and there was marked deterioration in mining conditions, and improvements in the working system and the mechanization of operations had been introduced to only a slight degree.

The proportion of open-pit operations has declined from year to year, causing a drop in the labor productivity index although there was an increase in individual open-pit and underground operations.

The proportions of ore obtained by open-pit methods was 1.5% of the total ore in 1950 and 15.4% in 1955 and was the result of bringing into exploitation portions of upper layers of the ore seam earlier considered below standard and for this reason not worked. The amount of ore in such sectors was very limited and the main amount of ore is extracted by underground methods from the lower levels.

The increase in the proportion of underground operations was accompanied by a shift to more difficult conditions of extraction in the lower layers marked by a great excess of water.

TABLE 8

Proportions of underground and open-pit mining %

1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Percentage of underground mining										
22.3	24.4	26.7	28.3	43.1	49.3	51.4	67.8	74.5	90.7	98.5
Percentage of open-pit mining										
77.7	75.6	73.3	71.7	56.9	50.7	48.6	32.3	25.5	9.3	1.5

Proportions of underground and open-pit mining %

1951	1952	1953	1954	1955
Percentage of underground mining				
99.65	92.2	91.9	84.1	84.6
Percentage of open-pit mining				
0.35	7.8	8.1	15.9	15.4

With a decrease in the proportion of open-pit operations there was an increase in the amount of labor used per ton of bauxites which also led to a reduction in labor productivity at the mines as a whole.

Since 1947, despite the continuing increase in the proportion of underground operations, there has been a continuous increase in labor productivity at the mines as a whole which can be explained

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by the mechanization of production processes and the extensive expansion of modern work methods.

In Fig. 2 we see the dynamics of labor productivity in underground operations during the period 1940-1955.

Underground operations started in 1938. Labor productivity, as a rule, was at a low level because of the lack of mechanization and an efficient working system.

In 1941 labor productivity increased 8-10% over 1940 as the result of working more productive sectors.

In 1942-1944 labor productivity dropped. During these years horizons were opened which lay below the level of the underground waters and working in them was complicated by excessive mine water.

The work of the mines was also greatly hampered by wartime difficulties caused by the lack of materials, mining equipment and tools. The absence of a sufficient number of qualified personnel and idle time of equipment led to failure to fulfill production norms and to a drop in labor productivity.

A positive factor in the work of the mines during the period 1943-1944 was the start of mechanization. Mechanization in stoping operations increased from 5.7% in 1942 to 22.4% in 1944.

Starting with 1942, clearing operations in drifting were mechanized. In 1943 21.3% and in 1944 28.8% of clearing operations in drifting were mechanized.

However, as the result of the negative influence of the above enumerated factors labor productivity declined despite the increase in mechanization.

Starting with 1945 labor productivity increased in underground operations which was achieved thanks to changes in the mining system. The shift to combined top slicing made possible more complete mechanization of the production processes (mechanized hauling increased to 44.1%).

As the result of improving the mining system labor productivity increased (per stope, underground, and per mine laborer).

In 1946 there was an extension of the combined mining system accompanied by an increase in mechanization of production processes

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(horse hauling of rock, manual hauling of timber to the stope completely eliminated) and in labor productivity.

Labor productivity in these blocks greatly exceeded the usual which was the result of the mechanization of production processes and correct labor management.

The increase in labor productivity was also accompanied by the extensive introduction of high-speed entry operations. It should be mentioned that the level of labor productivity would have been higher if the combined system of top slicing has been used to the necessary extent. In the meantime large sectors which could be worked by stoping with a broad working front and consequently high labor productivity were worked in part by ordinary procedures.

Labor productivity in open-pit operations during the period 1940-1945 was at approximately the same level, with the exception of 1944 when the production per mine worker was 72.1% of the 1940 level which can be explained by the degree of wear of the excavators and the absence of drilling equipment.

In the period 1946-1949 labor productivity of workers in open-pit operations rose markedly. This was furthered by socialist competition among workers in excavator teams. The principal factors which made for higher labor productivity among workers on excavator teams were:

mastery of their occupation by members of the excavator team;

consolidation of the workday (teams reduced the time for loading one train from 35-40 minutes to 20-25 minutes);

maintenance of excavators in good conditions, careful inspection and prompt elimination of minor defects during the shift, prompt precautionary repair as planned (teams greatly reduced the idle time of excavators for repairs which led to increased productivity of machinery);

The hourly production of the excavator was 37.9 cubic meters in 1945, 40.6 cu.m. in 1946, 41.4 cu.m. in 1947 and 41.9 cu.m. in 1948.

use of a bonus wage system;

strict coordination of the work of excavator teams with the work of train crews.

During the fifth five-year plan there was a continued increase in labor productivity, greatly surpassing the 1950 level (Table 9).

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In 1955 twice as much ore was produced as in 1950. Of the total increase in ore extraction more than half was achieved through the increase in labor productivity. For instance, in 1955 the proportion of increase due to an increase in the number of man-days worked was 40.9% and that due to increased labor productivity was 59.1%.

As we see in the data from Table 9 labor productivity with regard to the amount of rock removed per stope group was 48.8% higher in 1955 than 1950, for all underground workers 54.1% and for the workers in the surface divisions 46.3%.

TABLE (9)

DYNAMICS OF LABOR PRODUCTIVITY BY SEPARATE GROUPS OF WORKERS
1951-1955

Indexes	1950	1951	1952	1953	1954	1955
Labor product.in cu.m. of rock per stope worker in % of 1950	100	105.9	112.9	113.8	139.7	148.4
Per underground worker in % of 1950	100	122.4	123.6	129.5	144.8	154.1
Per worker in surface installation in % of 1950	100	111.9	120.9	123.8	137.2	146.3
Per mine worker in general	100	115.0	121.5	132.2	139.3	153.6

Labor productivity per mine worker in 1955 was 53.6% over that in 1950.

Such a difference in the rate of increase in labor productivity of the different groups was the result of changes in the structure of the labor force in the mines during these years.

For instance, in 1952 the ratio between the number of workers in the stope crews, underground operations, surface installations and total mine were 1: 1.9: 3: 5.4 mm while in 1955 this ratio was 1: 2.1: 3.2: 6.1.

This change was accompanied by a lag in the rate of growth in labor productivity in other groups as compared with that of workers in the stopes.

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4. Mechanization of Production Processes at Enterprises of the Aluminum Industry

There are exceedingly great possibilities for increasing labor productivity in the aluminum industry by reducing the amount of labor through mechanization and automatic control.

Problems in mechanization have been the focus of attention of the Party and government during the entire period of the development of the national economy.

The mechanization of processes utilizing much labor has an effect on increasing the efficient use of working time, easing labor conditions, reducing the auxiliary labor force and the length of work processes, increasing the skill of laborers and, consequently, on increasing labor productivity.

At plants in the aluminum industry considerable work has been done in recent years on the mechanization of heavy processes with the result that the basic processes in electrolytic and alumina production have been almost completely mechanized and manual labor is being used only in auxiliary and subsidiary sectors.

In the mining industry problems in mechanization are of special importance because of the difficult nature of the production processes.

The use of new equipment in the fifth five-year plan has made it possible to complete the mechanization of a number of basic processes in extracting the raw ore (Table 10).

TABLE 10

DYNAMICS OF THE LEVEL OF MECHANIZATION OF BASIC PROCESSES AT MINING ENTERPRISES OF THE ALUMINUM INDUSTRY (IN % OF TOTAL VOLUME OF ROCK) [NOTE: K.G. KASSIURA "DEVELOPMENT OF THE MINE BASE OF THE ALUMINUM INDUSTRY", BULLETIN OF THE TsIIN, NO. 6, 1957].

Process	1942	1943	1944	1945	1946	1949	1950	1955	1956
Clearing in drifting	[illegible]	21.8	29.8	55.0	58.5	75.2	80.0	94.0	94.5
Haulage in extracting	5.7	19.3	22.4	44.2	34.0	63.2	76.0	97.5	97.5
Underground hauling of rock					23.0	42.3	57.0	99.0	98.0
Extraction and loading of rock in open-pit operations	No data				90.0	No data	96.0	100.0	100.0

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The data showing the state of mechanization at the Northern Ural Bauxite Mines are cited in Table 11.

TABLE 11

MECHANIZATION OF BASIC PROCESSES AT THE NORTHERN URAL MINES 1940-1950
(in % to total volume)

Process	1940	1941	1942	1943	1944	1945	1946	1947	1948	1950
Drilling	100	100	100	100	100	100	100	100	100	100
Transport in stoping:										
mechanized			5.7	19.3	22.4	44.1	44.14	44.8	55.2	
gravity				17.4	10.8	16.2	16.6	24.7	15.2	77.0
manual	100	100	94.3	63.3	66.8	39.7	39.26	30.5	29.6	23.0
Underground haulage of rock:										
mechanized								2.96	17.5	65.9
horse-drawn							2.31	16.1	9.0	4.4
manual	100	100	100	100	100	100	97.69	80.94	73.5	29.7
Haulage on the surface:										
mechanized								1.66	13.9	50.8
manual	100	100	100	100	100	100	100	98.34	86.1	49.2
Clearing in drifting:										
mechanized				21.3	28.8	54.9	58.54	70.6	81.2	
gravity				4.7	5.2	7.1				
manual	100	100	100	74	66	38				

Removal of ore from the stope and its further transportation to the hauling drift are the most laborious operation in the extraction of bauxites.

In 1940-1941 the transportation of ore was by hand dumping and on carts. This required a great deal of labor and labor productivity was very low.

In 1943 the mines introduced the removal of ore from the stope by scrapers and gravity removal of ore from inclined galleries.

Since 1945 belt conveyors have been coming into use.

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In 1946-1947 scraper removal was extended (bilateral scraping and scraping at an angle).

In 1948-1950 great work was done on mechanizing transportation in stoping operations (up to 77.0%).

The process of underground hauling of rock was mechanized to the lowest degree. In 1940-1945 all the hauling of the rock waste was still done by hand.

In 1946 horse haulage was used for the first time but to a very slight degree (2.31%). In 1947 horses were doing 16.1% of all this work.

In 1947-1948 electric locomotives came into use for hauling in mine opening operations. The use of electric locomotives required increased speed in opening drifts.

In 1950 the proportion of manual labor was reduced to 29.7%.

Up to 1943 removal in drifting operations was done exclusively by hand (showelling, pushing in hand carts or rail cars). Labor productivity during this period was low. As a rule, up till 1943 the rate of tunneling did not exceed 25-30 linear meters per month. In the period 1943-1945 removal by scraper was adopted at the Northern Ural Bauxite Mines. In 1943 mechanized removal of rock in tunneling was 21.3%.

In 1943 gravity removal in sloping galleries was used for the first time (steep inclines required). This type accounted for 4.7%.

In 1945 removal by hand accounted for 38%.

The use of scrapers in removing the rock during tunneling operations resulted in an increase in opening drifts and a rise in labor productivity.

The start of the mechanization of rock clearing operations by using scrapers operating on a cyclical basis goes back to March 1943 when Sabirov's crew tunneled 73 linear meters as a single stope.

In July 1949 the crew under Stalin Prize Winner N. Minzaripov penetrated 254 linear meters of drift in a single stope. In 1950 a maximum tunneling rate of 268.6 linear meters per month was reached. During recent years mines have carried out more than 80 high-speed drifting operations.

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In Table 12 we have data on monthly tunneling rates by year.

TABLE 12

DATA SHOWING MONTHLY DRIFTING RATES IN 1943-1950
IN LINEAR METERS

Index	1943	1944	1945	1946	1947	1948	1949	1950
Average speed	73	90	118.7	127.3	135.5	132	134	135
Maximum speed	73	90	162.4	172	181.4	203.4	254	268.6

Starting with December 1945 Russian loaders were used in clearing rock from drifting operations.

Rock removal from drifting operations at the Northern Ural Bauxite Mines was the most highly mechanized process. The removal of the rock mass on the surface on the other hand was poorly mechanized. In 1940-1946 the transportation of the rock on the surface was done wholly by hand. In 1947-1948 some mines started to use scraper winches to transport ore on the surface. However the percentage of mechanized transportation on the surface was still unsatisfactory.

The percentage of hand transportation was 49.2% in 1950.

Boring operations, which are one of the most important in the production cycle, were wholly mechanized both in stoping and in mine opening operations. The number of boring hammers on January 1, 1956 as compared with January 1, 1951 had increased 84.4% while the degree of their use had increased by 8.3%. In 1950 mechanized and gravity transportation of ore was 77% in stoping operations while mechanized haulage reached 98.2% in 1955.

The level of mechanization in the removal of rock in mine-opening operations was higher in 1950 than the transportation of ore in stoping operations. In 1950 the removal of rock from mine-opening operations was 92.2% mechanized in 1955 and 97.9% in 1955 (Table 13).

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TABLE 13

DEGREE OF MECHANIZATION OF TRANSPORTATION OF ORE AND ROCK IN STOPING AND MINE-OPENING OPERATIONS

Index	1950	1951	1952	1953	1954	1955
Total volume of work in rock haulage in stoping, %:						
mechanized and gravity	77.0	81.0	92.0	96.5	97.7	98.2
by hand	23.0	19.0	8.0	3.5	2.3	1.8
Total volume of work in rock removal, %:						
mechanized	92.2	93.7	90.0	96.0	96.7	97.9
by hand	7.8	6.3	10.0	4.0	3.3	2.1

The increase in the number of scraper winches and loading machines was an important factor in increasing the growth in the mechanization of ore transportation in stoping operations and rock haulage in preparatory operations. For instance, the number of scraper winches in mines in 1955 was more than 3.7 times more than in 1950 while there were 215 times as many loading machines; the coefficient of use of the scraper winches at hand increased during this period from 0.79 to 0.84 and of loading machines from 0.45 to 0.57.

One of the conditions for the increase in labor productivity at the mines was the further mechanization of underground rock haulage and the transportation of rock on the surface (Table 14).

TABLE 14

DATA ON THE MECHANIZATION OF LABOR AT BAUXITE MINES

Index	1950	1951	1952	1953	1954	1955
Underground haulage of rock, %:						
mechanized	65.9	96.1	98.2	99.0	98.7	99.4
horse-drawn	4.4	2.9				
by hand	20.7	1.0	1.8	1.0	1.3	0.6
Transportation of rock on the surface:						
mechanized	50.8	57.3	68.4	76.4	93.0	94.0
by hand	49.2	42.7	31.6	23.6	7.0	6.0

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An important factor in assuring the increase in the mechanization of underground hauling and transportation of rock on the surface was the constant growth in means of transportation during this period.

The number of electric locomotives at the beginning of 1956 was 4.5 times greater than at the beginning of 1951. The number of cars increased more than 150% during this same period.

As the result of work done on mechanizing the basic processes (delivery, clearing, underground haulage) the proportion of stope workers to the total number of workers dropped and stood at 33% in 1952 and 31% in 1955 while the ratio to the number of mine workers in general and the number of workers in production processes was 18.7 and 16.3% respectively.

Thus labor productivity among mine workers at the Northern Ural Bauxite Mines doubled from 1940 to 1955 as the result of improvement in stoping methods, the mechanization of basic production processes, and the use of improved work organization in the stope.

In the alumina and electrolytic sections the basic production processes were more completely mechanized and manual labor was utilized in auxiliary and subsidiary sectors. The use of mechanization through local ingenuity and adaptations made it possible to reduce considerably the number of auxiliary workers. For instance, at the Ural Aluminum Plant in 1949-1950 there was a growth in production with a concomitant reduction in the labor force through mechanization.

In the electrolytic divisions, difficult operations in transporting the alumina, anode material, cryolite and aluminum fluoride were done wholly with electric trucks which made it possible to reduce considerably the transportation labor force.

Heavy physical labor in pulling out the pins has been mechanized. Kosyrev machines and Shishkin hydraulic jacks have been used. In addition Snezhko pneumatic machinery operating on a percussion principle have been used to pull the pins out of anodes of electrolytic cells.

In improving the design of the pneumatic machines the same designer made and introduced a new improved pneumatic machine which eliminated the necessity for manual labor in pulling out the pins.

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At some plants the Anikin machine has been used for driving pins into the anodes of electrolytic cells. The mechanization of the process of pin driving has speeded up this operation several times and lightened the labor of the anode operators.

The difficult process of servicing the cells (breaking through the top crust of the electrolyte and breaking up the crust on the sides of the aluminum electrolysers) was for a long time done by hand with crowbars and with pneumatic drills. At present a new pneumatic mechanism is used in breaking up the top and side crust which has made it possible to mechanize a difficult and labor-consuming operation, improve and speed up the process of servicing the cells and improving working conditions from a sanitation point of view.

Wedge-type bar-pin contacts have been adopted for electrolysers and a pneumatic drill is used to drive in and pull out the wedge. This measure has made it possible to improve working conditions, increase labor productivity and achieve great economy of electric power since the average drop in voltage in the wedge bar-pin contact is 4-6 millivolts instead of 15 millivolts.

Work is being done in electrolytic sections on installing mechanisms with electric drive for raising anodes from the cells, for mechanizing the raising of louvers on the cells, and testing new machinery designed by Bocharov, Gerasimov and others for breaking through the electrolyte crust.

Cleaning the dust from anodes by hand before loading the anode material has been replaced by cleaning with an air spray which improved the quality of anode cleaning and reduced the work time involved in this operation. The loading of the anode material in the form of large briquets has made it possible to use gantry cranes for this operation. The casting of wire bars and silumin has been mechanized.

In alumina shops at the Ural plant mechanization is employed in unloading, grinding, screening and feeding the charge into the lime furnaces and transporting lime into the flotation division.

Remote control from the upper level has been organized for sampling cranes on the white side. Pulp and solutions are being removed by pump from the apparatus before cleaning and the apparatus is cleaned by water at high pressure. Parts are hoisted vertically by winches which has made it possible to reduce the number of auxiliary workers carrying up parts. Conveyors are used for unloading soda.

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Machinery is used for loading the balls into the ball mills by overhead line and electric magnet in the first block of the alumina shop, etc.

Considerable work on the mechanization of major processes in the alumina sections of other plants has also been done.

Instructions from the Party and the government relating to the poor mechanization of auxiliary processes at plants where basic processes are highly mechanized also apply to the aluminum industry.

In the auxiliary shops of aluminum plants there are a number of sectors now being mechanized.

In the repair shops of some plants there are no machines for hoisting parts and loads during repair operations; above some apparatus undergoing periodical repairs there is no auxiliary equipment such as cranes, overhead conveyors, etc. with the result that the speed of repair jobs is slowed down and the work of skilled laborers is used inefficiently. In railroad shops aluminum ingots are loaded and piece goods are unloaded by hand.

Despite the great amount of work on mechanizing heavy processes done in recent years at aluminum plants it cannot be considered satisfactory or equally well done at all establishments.

We must provide for further mechanization of all heavy jobs in servicing cells in electrolytic sections and the various sectors of other sections, total mechanization of all transportation within the sections by using the best types of conveying equipment (use of dump cars for alumina sections with a great flow of material; loading and unloading pulverized materials in special self-dumping cars); maximum use of pneumatic tube transportation; automatic control of separate operations in alumina sections and central control of production processes by providing for a complete supply of control, measuring and signalling apparatus. The mechanization of loading and unloading operations makes it possible to get rid of the greater part of heavy unskilled labor used in a given branch and to reduce the number of the auxiliary and subsidiary labor force.

Considerable influence on reducing the number of workers engaged in repair in the aluminum industry might be exerted by centralized production of spare parts for the aluminum industry at specialized repair and machine plants. The organization of centralized production for the principal spare parts at specialized repair and machine plants will contribute to an increase in labor

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productivity. Such specialized repair and machine plants, replacing production on a limited or individual production basis at the individual aluminum establishments, must be organized in the various regions and serve the group of establishments located in that region.

The effectiveness of mechanization is also determined by the degree of use of the machinery. Machinery idle time sometimes reaches very great proportions. For this reason it is important to campaign for the total utilization of machinery now available at plants (truck-mounted cranes, steam cranes with tracks, various conveyors).

5. Factors in the Growth in Labor Productivity Related to the Socialist Organization of Labor

With these systems of raw material extraction, alumina production and its layout and existing designs of electrolytic cells, considerable influence on labor productivity is exerted at different enterprises by the organization of labor and the wage system, the provision of advanced training for workers, the degree of time-use efficiency, the adoption of up-to-date methods, working conditions and other questions connected with the functioning of the labor force.

The level of labor productivity depends to a great extent on the level of skill and the length of employment at establishments in the aluminum industry.

The skill of the labor staff of the different enterprises depends on the structure of the sections and on the qualifications of workers in the different shops.

The relative reduction in the number of poorly skilled workers and the corresponding increase in the number of workers of great and average skill at the Northern Ural Bauxite Mines is indicated by the increase in the number of skilled workers (the proportion of highly skilled workers rose from 20% in 1952 to 24.5% in 1955).

The average wage category of workers in the industrial production group of the Northern Ural Bauxite Mines was 5.26 in 1955 as against 4.8 in 1950 and 3.85 in 1946. The average wage category of mine workers (5.45) is higher than workers in the auxiliary sections (5.0).

This was achieved thanks to well organized work in training personnel at the enterprises.

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The average wage category of workers at the Ural Aluminum Plant during the period 1942-1950 is illustrated by the data in Table 17.

TABLE 15

AVERAGE WAGE CATEGORY OF WORKERS AT THE URAL ALUMINUM PLANT IN 1942-1950

	1942	1943	1944	1945	1946	1947	1948	1949	1950
Entire plant	5.0	4.8	4.7	4.6	4.6	4.7	4.65	4.7	5.0
Including the basic sections	5.5	5.4	5.3	5.2	5.1	5.1	5.0	5.0	5.6
Auxiliary sections	4.5	4.4	4.5	4.3	4.7	4.6	4.4	4.6	4.6

The most qualified personnel are employed in the electrolytic, electrothermal and power sections.

The average wage category in the electrolytic sections fluctuated between 5.5 and 5.7, while among workers in basic production 6.5-6.8, in the electrolytic section 5.2-5.5 and among workers in basic production 5.6-6 respectively.

In the alumina sections and in the calcination sections the average wage category fluctuated between 4.5 and 4.8 and among workers in basic production from 5 to 5.4. The highest average wage category was reached in the electrolytic sections of the Bogoslovskoye Aluminum Plant (5.85).

The number of skilled workers coming to the aluminum plants from factory schools and technical schools was 9-15% of the total number of workers.

Up to 1947 a very small number of workers from those who had finished the factory schools remained in employment at the aluminum plants. Young workers who had finished the factory schools and technical schools were employed primarily in the basic sections, alumina and electrolytic, and in the substations, repair and founding shops.

The turnover of workers in the aluminum industry was high.

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The main reasons for the turnover were the difficult working conditions in the electrolytic, electrode and calcination shops (poor ventilation, high gas and dust content of the air), unsatisfactory wages of a large number of occupations in the Northern Ural Bauxite Mines by comparison with workers in other enterprises in the same district, whose pay was based on higher wage scales, and poor housing conditions.

The lack of housing caused an increase in worker turnover at all aluminum enterprises.

In order to keep workers in the aluminum industry a decree of the government in 1948 extended the regulations on wages for workers in the Far North to workers in the Northern Ural Bauxite Mines.

By a decree of the Council of Ministers of the USSR "On increasing wages and constructing housing for workers and engineering and technical personnel at plants and construction sites in the Urals, Siberia and the Far East", there was a 20% increase in wages for workers and engineering and technical personnel in the leading branches of industry in these regions as of September 1, 1946.

After 1948 there was considerable housing construction by the Northern Ural Bauxite Mines and other enterprises of the aluminum industry as well as construction of individual homes on favorable terms by workers and employees.

A decree of the government regarding workers, managerial, and engineering and technical personnel at enterprises in the nonferrous metals industry established advantages and concessions for temporary disability and pension insurance, the award of orders and medals, and yearly compensation for years of service.

These decrees and a number of other governmental measures aimed at improving the wages and living conditions of workers in the aluminum industry as well as the work done on mechanizing the processing requiring the most labor and on improving working conditions played a decisive role in reducing the labor force turnover in the industry as a whole and at individual enterprises.

During the fifth five-year plan labor turnover was reduced considerably at the majority of aluminum plants . For instance, at the Ural Aluminum Plant the turnover was 15.1% in 1955 as compared with 20.7% in 1950.

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Further expansion of housing construction, improvement in the living conditions of workers, and an improved wage system to give the workers greater participation in the results of their labor have been the basis for keeping workers at their places of employment.

6. Organization of a System for Establishing Production Standards

Of great importance in the increase in labor productivity is well arranged work in establishing production standards.

Production standards must be the basis for the correct organization of labor and production. In order to establish standards with a technological basis an analytical method must be adopted.

In this system technologically based standards are computed on the basis of a detailed analysis of the technical process and the system, the organization of labor and the working site, a detailed verification of all production possibilities and an all-around consideration of the advanced work practices of innovators.

Standards based on practice and statistics do not take into consideration the achievements of the most progressive workers, conceal shortcomings in the organization of labor and production, do not mobilize workers and engineering and technical personnel towards overcoming these shortcomings and for the campaign to fulfill the state plan and lead instead to an unfounded overdisbursement of wage funds.

Unfortunately standards based on practice and statistics are still in effect at establishments in the aluminum industry (Table 16).

TABLE 16

ANALYSIS OF CURRENT PRODUCTION STANDARDS IN EFFECT IN THE ALUMINUM INDUSTRY, IN %

Name of Plant	Method for establishing current standards	1940	1941	1946	1950	1955	1956
Ural Aluminum Plant	Technologically based	1.2	10.5	39.7	67	56.5	65.6
	Practical-statistical	98.8	89.5	60.3	33	43.5	34.4
Stalin Aluminum Plant	Technologically based				39	55.3	58.5
	Practical-statistical				61	44.7	41.5

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The data cited indicate that the percentage of standards established on the basis of a technical analysis and by photo-chronometric methods has been increasing at aluminum plants. However the percentage of practical-statistical standards is still high.

Practical statistical standards are used primarily in repair operations in the basic and auxiliary divisions. They do great harm to production, leading to overdisbursement of the wage fund and do not stimulate labor productivity as they should. The dynamics of the meeting of standards during the period 1950-1956 shows that the greatest overfulfillment of standards was to be found among auxiliary workers working under practical-statistical standards. This is evident from the following data: the overfulfillment of production standards in all aluminum plants was 135% in 1950 with workers in the production divisions having 125.4% and workers in the auxiliary divisions 150.9%.

The average degree to which standards were met at the Northern Ural Bauxite Mines is indicated in the following fashion,%:

	1949	1950
Throughout the mines:	137	130.6
in production divisions	128.5	120
in auxiliary divisions	146	143

At the Ural Aluminum Plant the average satisfaction of standards in the main divisions (in %) was 106.4 in 1956 while it was 161.6 in the auxiliary divisions; at the Volkhovskoye Aluminum Plant it was 134.7 in 1955 and 129.6 in 1956 for workers in the basic divisions while in the auxiliary divisions it was 154.5 and 164.1 respectively; at the Dneprovsk Aluminum Plant in 1956 it was 123.1 for workers in the basic divisions and 161.6 for workers in auxiliary divisions.

Repair operations are characterized by a great diversity and plurality of standards. Practice employed in establishing standards for repair operations in the alumina and electrolytic sections has a great number of defects. In the alumina sections there are collections of standards for separate repair operations. These standards were drawn up many years ago and have not been verified by photochronometric observations. Time standards encompass a great number of operations in repairing different parts of the apparatus without indications for the exact volume of work involved (there is no schedule of all operations involved in repairing a given part). The absence of operational standards for repair work has led to an incorrect determination of the necessary expenditures of time and as a consequence there has been a high percentage of overfulfillment of production standards.

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The establishment of standards for repair operations in both the basic and auxiliary divisions followed the satisfaction of standards in accordance with actual expenditures of time which has not stimulated an increase in labor productivity.

Despite an almost yearly revision of standards, the degree to which they have been met in the auxiliary division has continued rather high, on the order of 130-160%.

All these data indicate the laxity of standards now in effect.

The rate of increase in labor productivity has to a great extent been weakened by too low production standards for operations in the auxiliary occupations. For this reason the number of auxiliary workers has been too high and this has led to a reduction in labor productivity throughout the plant as a whole.

A really efficient use of work time serves as a great potential for increasing labor productivity. The degree of efficient utilization of work time is one of the basic indications of the degree of efficiency of current production organization which has a direct effect on the level of labor productivity. In practice, however, problems in the efficient utilization of work time and in getting more out of the work day have frequently not been given sufficient attention.

An analysis made of the use of work time during a portion of the year and the work day at different plants in the aluminum industry revealed the occurrence of great losses in work time.

As shown by data for a number of years, approximately 71-77% of the total number of working hours in the calendar year were utilized at plants in the aluminum industry. During the war there was a greater use of the total amount of calendar work time through reductions in leave time and through operating with no free days a week. During the postwar period the amount of calendar work time utilized was reduced. During all the war years and some of the postwar years there was a great percentage of the work time not used through illness, which made up 4-5.5% of the total amount of work time available.

As a result of strengthening labor discipline and improving the organization of labor, absences from work have decreased in number from year to year. For instance, at the Stalin plant absences made up 0.6% of the total amount of calendar work time in 1946 but only 0.05% in the period 1949-1950. At the Ural plant it was 0.06%.

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During the fifth five-year plan the average number of days worked per year per worker increased considerably. In 1955 at the Northern Ural Bauxite Mines each worker averaged 74% of the total time, at the Volkhovskoye Aluminum Plant 75.6%, at the Dnepr Aluminum Plant 74% and at the Tikhvin Alumina Plant 76%. The increase in the number of days worked was influenced by the reduction in loss of work time through illness and voluntary absences.

Possibilities for increasing labor productivity through the more thorough utilization of work time during the year include a reduction in illness among workers by improving working conditions, by reducing approved absences and by complete elimination of unauthorized absences.

As a result of eliminating these losses the utilization of the working time during the year can be increased.

Labor productivity during each work shift depends not only on the use of time in carrying out individual operations as determined by the technology of production and the skill of the worker but on the use of the shift's work time as a whole, i.e. length of idle time within the shift. Depending on this a greater or lesser number of operations can be carried out during a shift.

The analysis made of the use of work time over a period of years at the Ural Aluminum Plant showed that losses of time within each work shift was 13.7-25.9% of the time worked.

In the auxiliary divisions the degree of work time utilization was lower than in the basic divisions.

The failure to utilize the work day fully in the basic divisions is largely due to idle time depending on the workers and on idle time of an organization nature caused by interruptions in the delivery of bauxite and caustic (1942, 1945 in the alumina sections), coal tar pitch and coke (1944, 1946 in the electrode section), charcoal (1944-1945 in the electrothermal sections), interruptions in the power supply (electricity supply in the electrolytic sections and steam supply in the alumina sections).

Idle time of a technical nature are in the majority of cases connected with breakdowns or accidents with equipment.

Observations made of teams of anode operators showed that unsatisfactory utilization of work time was due to lack of transportation equipment in crews engaged in manually pulling out pins and in manually raising the pins.

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In crews engaged in shifting contacts there was inefficient use of working time because of the lack of standardization in metal items.

In crews engaged in raising the anode frames there were many instances of idle time (approximately 17% of working time) caused by waiting for hoisting mechanisms and frames.

The lack of solid production standards for separate operations caused insufficiently intense work under the indirect piecework wage system.

Photographs of the working time of leading workers showed a high percentage of the working day utilized with exceptionally productive labor. Leading workers revealed the causes of enormous losses of time during the work day, led a persistent campaign to eliminate them and achieved considerable results in improving the use of working time.

Active working time among metal tappers reached 94%, among autoclave operators 94-98.9%, and among decomposer operators 77%, while the remaining time was spent in auxiliary and opening and closing operations. Among workers in the grinding section and the evaporation section there was also a highly efficient use of the work day.

A 1955 study on the use of working time in stope brigades in extraction operations at the Northern Ural Bauxite Mines showed that work time losses for reasons of organization or technology reached 22.6% (lack of cars, timbering, electric power, compressed air, faulty operation of machinery, waiting for blasters, lateness on the job and leaving early).

The elimination of losses in working time for reasons of organization or technology among stope brigades in extraction operations would make it possible to increase the number of cycles during a 24-hour period.

An analysis of the use of work time at the Northern Ural Bauxite Mines showed that idle time and losses of work time for organizational or technical reasons among stope workers of leading brigades in extraction operations (Lyuta brigade) were 13.7% as compared with 22.6% for the mines as a whole.

In the auxiliary divisions inefficient use of time results from idle time depending on the workers themselves and idle time for

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causes of an organizational nature. Idle time depending on the workers result from a lack of tight enough production standards in these divisions which reduces the efficient use of the work day as well as from insufficient control over production and insufficient instruction from the foremen during the shift. Idle time of an organizational nature in the auxiliary shops results from insufficient precision in the organization of the work such as: failure to supply spare parts and tools, transportation equipment, lack of preparation of materials, parts, late delivery of drawings to the site of operations (in the machine repair shops), defects in operation planning and in production preparation.

At the Ural plant the use of the work day increased to 88% but at the same time idle time due to the workers themselves remained high at 7.2%.

At the Stalin plant time losses through the factory were 18.7% including those due to the workers 11.3%, those of an organizational nature 1.3%, and those of a technical nature 6.1%.

At the Bogoslovskoye plant time losses throughout the factory ran to 12.34%.

The increase in the efficient use of work time at plants during the postwar years was helped by improved production organization, mechanization and the combination of separate occupations.

Filling up the working day in basic and auxiliary divisions is one of the really important objectives in the aluminum industry for the purpose of increasing labor productivity still further.

Maximum efficiency in the utilization of the work day may be assured by improving prodution and labor organization in separate sectors through the introduction of up-to-date work methods, by the mechanization of difficult processes, by providing the necessary amount of transportation machinery, by preliminary preparation for production processes, by separating auxiliary and subsidiary operations from basic processes, by improving the system for supplying material and equipment, by combing occupations and the operating of several units, by greater instruction, and through the establishment of just production standards.

An analysis of the use of work time and the status of technical standards at enterprises in the aluminum industry has shown that the introduction of technically based standards which take into account the achievements of leading workers makes it possible to utilize great potentials for further increasing labor productivity.

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7. Providing Further Training for Personnel

The current introduction of new equipment in the aluminum industry and tasks in a fuller mastery of the latest equipment make increased demands on the skill of workers.

Mastery of the latest equipment, and raising the technical, political and cultural level of workers open great possibilities for developing their diverse capacities and creating a new type of worker distinct from the laborer under capitalism. Engels pointed out that under socialism "the management of production by the forces of society itself and the resultant new expansion of production will call for completely new people and will create them." [Note: K. Marx and F. Engels, Complete Works, vol.5, p.478, 1929 edition]

The Communist Party and the state have given an exceptional amount of attention to the problem of raising the general and occupational level of the Soviet worker.

Along with the system of state labor reserves which provides a constant large-scale supply of skilled personnel for socialist production, the training and provision of advanced training for workers is being carried out systematically through various forms of instruction on the job.

At plants in the aluminum industry new personnel is instructed through courses and by assigning individual apprentices to highly-skilled workers and by retraining working personnel through a minimum of technical instruction, through schools giving instruction in the latest work methods, by training in a second occupation, by courses in a specific subject, and by advance training for engineering and technical personnel.

The number of workers encompassed by all types of production and technical instruction is constantly increasing.

In connection with the introduction of the latest equipment, the improvement of production methods, and mechanization and automatization in production processes during the postwar years, greater attention has been given to problems in production and technical instruction for workers in the aluminum industry. The number of workers covered by the various types of instruction is considerable, reaching 30-50% of the total number of workers at some enterprises.

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Training in a second occupation has become widespread. Instruction in related occupations aims at combining both basic and auxiliary occupations in the same person. For instance, the following basic occupations in the alumina shops are compatible: classifier and miller, charge firer and operator of lime furnaces. Combinations of basic and auxiliary occupations takes place in the following pairs: technician and mechanic, evaporator and pump operators, foundrymen in the foundry shop of electrolytic sections have the right to operate overhead conveyors; technicians in the alumina section have the right to operate winches, etc.

In electrolytic sections schools dealing with up-to-date work methods were organized in brigades with poor productivity indexes (failure to fulfill the plan on the basis of current unit, power unit, low-grade metal production).

The schools were directed by highly skilled brigade leaders and crew chiefs who demonstrated the most efficient methods right on the spot.

These schools also had consultants from among the engineering and technical personnel. Along with the school director the consultant observed the work of those receiving instruction and pointed out shortcomings in their work.

The results of instruction in these modern-methods schools can be seen by comparing work factors before and following instruction. The schools serve to exchange information between the best brigades and to introduce the best work methods.

Instruction in these schools have given exceptionally good results. In Table 17 we have data showing the results of instruction in a brigade of workers in Building 4 at the Ural Aluminum Plant.

TABLE 17

WORK INDEXES FOR A BRIGADE AT THE URAL ALUMINUM PLANT WHICH TOOK INSTRUCTION AT THE MODERN-METHODS SCHOOL

	Percentage of plan fulfillment	Per current unit, %	Output energy, gram/kw/hr	Grade of aluminum in %: Grade A0	Grade A1
Before instruction	78.4	72	54.5	4.9	57.7
After instruction	100.3	82.3	57.7	7	82

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Comrade Boyevodin's brigade (Bldg. No.1) met production standards by 115-118% following instruction in the school with output per unit of current 86.5% and output of higher grades of metal to 99.6%.

At the Volkhovskoye Aluminum Plant production leaders, electrolytic workers Fedorov and Mogutov, after successfully finishing the school for foremen gave instructions in their work methods to a group of electrolytic workers.

As a result of instruction, the brigades of Comrades Timashev, Karusin and Volkov markedly increased output based on current and energy. Electrolytic brigade leaders Kosenkov and Pakhletskiy taught their work methods to heretofore lagging brigades of Comrades Morozkov and Yegorov. Following completion of the school the latter increased production per current unit from 89.2 to 90.35% and output per energy unit from 59.44 to 60.24 gram/kilowatt/hour.

There has been great expansion of schools for the collective experience of leading workers and innovators.

In these schools a study is made of the experience of individual leading workers. Leaders and innovators of the establishments get acquainted with new achievements in science and technology and with progressive practices in the field of alumina production and electrolysis.

Up-to-date work methods are also studied in interfactory schools. For instance, in 1956 at the Ural Aluminum Plant two interfactory schools were conducted for the Ural and Bogoslovskoye Aluminum Plants on the repair of electrolytic cells and for steel foundrymen of plants in the city of Kamensk-Ural'skiy.

Schools for leading workers and innovators assist workers in acquiring production skills and in mastering highly efficient labor methods which assure an increase in the production of high-grade goods.

In courses for specific purposes, studies are made of separate types of operations and separate sectors of production.

The topic make-up of courses for specific purposes is most diverse, for instance, servicing and operating "Kelly" filters, for Dorr apparatus operators and filter operators in the alumina section.

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With the great number of workers at aluminum plants engaged in study through the technical minimum courses, schools for leading workers and the study of a second occupation, insufficient attention was given to problems in providing advanced training for engineering and technical personnel.

The aluminum industry is faced with a great objective, that of increasing the theoretical knowledge of engineering and technical personnel who have spent a long time in industry but have not finished technical schools and of further increasing the extent of on the job training.

8. Organization of Wages

Along with the potentials already discussed for increasing labor productivity in the aluminum industry there is the importance of a correct organization of wages.

Up to 1940 there was a marked inequality in pay for workers in the nonferrous metal industry.

The existence of a great number of scales led to an equalizing of the pay for skilled and unskilled labor.

The poor organization of labor and wages had a particular effect on the unsatisfactory operation of the mining industry.

With the aim of meeting the labor productivity plan the People's Commissariat for the Nonferrous Metal Industry in 1940 made a review of production standards and the wage system. Wage scales were reviewed for workers in all branches of the nonferrous metal industry. An adjustment of the wage system at this time amounted to tightening up on wages of workers in the basic nonferrous metal productions and in separating workers in the leading occupations as well as workers in underground, heavy and mining operations.

It would be pointed out that the wage reform of 1940 did not eliminate many shortcomings in the wage system. There remained a great number of scales differing in their scope.

During the Patriotic War in a number of branches of industry and in the coal industry and the nonferrous metal industry in particular, there was a sharp increase in wages. Although wages for workers in the nonferrous metal industry increased over the prewar level, it was not as much as in other branches of industry.

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Considering the importance of the nonferrous metal industry in the national economy and in the national defense, by the decree of July 6, 1944 aimed at improving the material status of workers in the nonferrous industry and in adjusting the wage system, the government greatly increased the wages of workers and engineering and technical personnel.

In carrying out the decree of the government, considerable work was done in 1944 in the nonferrous metal industry in adjusting the wage system.

For mining enterprises a uniform 10-category pay scale was established and for the metallurgical and metalworking industries an 8-category scale.

Within the limits of the wage system for mining and metallurgical enterprises daily wage scales were established which provided for a difference in wages for workers in the key jobs, other piece workers and employees on a time basis. All the enterprises were subdivided on the bases of pay scales: mining were divided into two and metallurgical into three groups. Within one pay scale six rates were established for mining enterprises and nine different rates for metallurgical enterprises.

A further increase in wages was carried out in 1946. This year the wages were raised twice. The first raise was put through in accordance with a decree of the Council of Ministers of the USSR for workers employed in mining and heavy jobs in metallurgical and mining divisions as well as in loading and unloading operations at enterprises in the Urals, Siberia and the Far East. Wages for these workers were increased 20%. A second raise was put through in accordance with a governmental decree on a bread supplement for low-pay workers and employees. These supplements were included in the fixed portion of the wages and introduced into piece-work pay rates with the result that the number of pay scales current at enterprises increased from one to three (where the 20% increase did not apply) and to six (where the 20% increase did apply). The total number of pay scales for all three groups of enterprises reached 18.

In addition to the formation of a number of pay scales which complicated the computation of wages at enterprises, these changes led to a disruption of the established permanent uniform ratios between wage coefficients. The inclusion of supplements of rations in the wage scale led to raising the wage coefficients of the lower categories and to bringing the first and highest categories closer together.

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Correct pay scales, in order to eliminate equalizations in the wages of workers of different degrees of skill and in order to stimulate workers to acquiring greater skill, must guarantee a more pronounced increase in pay when moving from the lower categories to the higher ones. The latter can be achieved by extending the degree of increase in pay in the higher categories. Data showing the increase in wages in the pay scales in effect are illustrated in Table 18.

Scales then in effect did not meet the requirements for a correct organization of wages aimed at increase labor productivity by giving each worker a monetary advantage in increasing his skill. For instance, in the scale with a 20% supplement the difference between categories for key piece workers in categories 2 to 4 is 15-16% and in category 8 it is 8.7%. In the scale for other piece workers the breaks between categories in passing drops from category 4 to 5 from 16.2 to 14.7% and from category 7 to 8 from 16 to 9.1%.

TABLE 18

DIFFERENTIAL BETWEEN ADJACENT CATEGORIES
(IN % OF THE PRECEDING CATEGORY)

	Category II	III	IV	V	VI	VII	VIII
For workers receiving 20% supplement							
Key piece workers	15.0	16.5	15.0	17.0	15.5	8.7	19.9
Other piece workers	11.0	16.2	16.2	14.7	16.2	16.0	9.1
Time workers	13.0	12.4	15.0	15.9	14.3	17.1	15.9
For workers not receiving the 20% supplement							
Key piece workers	11.0	16.2	16.2	15.4	16.5	16.0	8.7
Other piece workers	13.0	12.5	19.0	12.5	13.5	17.0	16.6
Time workers	12.0	14.3	11.8	14.7	15.3	14.9	17.1

In the scale for workers on a time basis we find changes in the differentials between categories of a sporadic nature (drop in advancing to VII from 17.1 to 15.9%). An analogous picture is observed in scales for workers who do not receive the 20% supplement.

Another shortcoming of the pay scales was the fact that they did not assure a constant ratio in the pay of piece workers and workers by the hour.

Thus the increase in the pay scales lead to a certain leveling in pay conditions which was the cause of a peculiar equalizing of wages.

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The ten-category scales in effect at mining enterprises of the aluminum industry as well as the eight-category scales of metallurgical plants did not provide for a constantly increasing difference in pay between categories from the lowest to the highest.

Pay scales in effect since 1946 lagged greatly behind the wage level achieved by workers which led to the use of lower, unfounded production standards and hindered the increase in labor productivity. Pay based on the scale amounted to 50-60% of the total wages of workers.

In accordance with the decree of the Central Committee of the CPSU and the Council of Ministers of the USSR of August [illegible], 1958 concerning the introduction of a shorter working day and new pay rates for workers, employees and engineering and [illegible] personnel in the nonferrous metal industry between August 1958 [illegible] September 1959, there has been a gradual shift in enterprises of the aluminum industry to a uniform seven-category pay scale effective both in mining and metallurgical enterprises. At the same time new more accurate pay scale manuals are being introduced, reflecting changes in the occupational composition of the labor force caused by the development of equipment and technology and anticipating a pay rate for all categories.

In earlier scales there was no assurance of filling the lower categories. Pay scales were different depending on the functions performed (for workers employed in underground mining, for production workers in open-pit operations, for workers in shop sections and divisions with hot, harmful and difficult working conditions in metallurgical and chemical metallurgy processes, ore concentration and agglomeration, in the production of carbon and graphite electrodes, for workers in other divisions in these types of production, for workers in auxiliary divisions and auxiliary sectors of the basic divisions, etc.)

In this case workers employed in the basic production processes were subject to no difference between the rates of piece and hour workers (as had previously been the case with pay rates); different pay rates are introduced for workers in auxiliary divisions and auxiliary sectors of the main divisions; piece workers in hot, heavy and harmful jobs, piece workers working in the cold and per diem workers in hot, heavy and harmful jobs and for per diem workers in cold operations.

The new pay scale anticipates a uniform difference in pay from the lowest categories to the highest which is an effective stimulus to increasing the skill of workers.

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Another important lever in the organization of wages is the systems which regulate the amount paid out depending on quantitative and qualitative work factors.

In the aluminum industry the following wa[illegible] systems have been used: 1) piece work, 2) progressive work, 3) [illegible]cework-bonus system, 4) per diem, 5) per diem-bonus.

In basic divisions the piecework system is the principal form of pay. As of January 1, 1955 this system applied to 72.2% of the workers through the entire aluminum industry with 76.0% at the Ural plant, 66.7% at the Stalin plant, 75.0% at Bogoslovskoye, 72.6% at Volkhov and 75.1% at the Dneprovsk plant.

The proportion of pieceworkers has declined somewhat in recent years. For example at the Stalin Aluminum Plant piecework was done by 65.4% of the workers in 1955 and 57.0% in 1956.

The rather high proportion of per diem workers can be explained by the presence of a large number of workers in services performed by rotation who are paid on a time basis.

Under the direct piecework wage system are auxiliary workers in the basic divisions and workers in auxiliary divisions. In the electrolytic shops those paid by piecework are siphon operators, pourers, decanters, chlorinator operators, i.e. basic but not key occupations.

Approximately 25-30% of the workers in aluminum plants are paid on a time basis. Time-based pay is more widespread in the auxiliary divisions where it accounts for 40-50% of the total.

In the basic divisions the time-based system of wages accounts for 8-15% of the total. Time payment is used for workers in technical control and for workers engaged primarily in services performed on a rotating basis where it is not possible to organize an accounting system for the labor employed and to establish production standards.

In the electrolytic shops of aluminum plants workers operating the travelling cranes and the anode system, i.e. depending on the amount of metal turned out by the building unit.

The progressive piecework pay system, used in decisive areas of production in basic divisions, has stimulated the increase in labor productivity. The computing of progressive rates starts with the first percentage of overage of the standard up to the highest rate obtained.

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The progressive piecework systems in effect have had different scales of progressive rates.

At aluminum enterprises a number of bonus provisions are in operation.

As a result of a large number of factors concerning the granting of bonuses the pay of electrolytic operators has been composed of numerous stratifications making wage payments more complicated and not readily understood by the workers.

For instance, the wages of workers in the electrolytic divisions of the Ural plant has been composed of the following elements:

base pay scale
progressive additions for exceeding standards
bonuses (30% of base pay) for exceeding production standards
bonuses for higher grade metal
bonuses for reaching the planned output of metal
bonuses for savings in electric power.

In the alumina sections workers have been granted bonuses for economizing on steam and for returning the condensate to the heat-power electric station.

The granting of bonuses to workers paid on a time basis was done at aluminum plants on the basis of 19 principles. Characteristic of the granting of bonuses to those paid on a time basis is the fact that bonus indexes coincide with the direct obligations of a worker in his principal job and have the nature of a guaranteed supplement to his wages.

A large part of instructions on the awarding of bonuses are quite ineffective from the point of view of improving the quality of work and increasing labor productivity since these instructions on bonuses and their application directly and sometimes indirectly do not depend on those granted the bonuses.

For instance, current bonus regulations in a number of cases have served only as a means for a mechanical increase in wages and have been converted into a brake on the further growth of labor productivity. An adjustment of the bonus system is an urgent necessity.

In the aluminum industry wages have increased constantly.

All changes in the organization of wages during the Great Patriotic War and during the fourth five-year plan in the aluminum

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industry were directed at improving the monetary participation of workers in the results of their labor.

The average yearly pay of workers in the aluminum industry had increased by 1950 to 271% of the 1941 level.

During the fifth five-year plan there was a further increase in the average yearly wages. For instance, at the Ural Aluminum Plant the average yearly wages increased by 12.1% from 1950 to 1955, by 34% at the Stalin Plant, by 12.4 at Volkhov, by 16.5% at the Dneprovsk plant and 12% at the Kanaker plant.

The high rate of increase in the average yearly wages in the aluminum industry reflects the policy of the Party and the government aimed at stimulating the development of this branch.

In some years in this branch there have been unfavorable ratios between labor productivity and wage increases. Labor productivity has increased more slowly than the average wage.

On the basis of instructions from the Party and government measures were adopted to increase labor productivity and regulate wages with the result that at the end of the fourth five-year plan a favorable ratio between the increase in labor productivity and the increase in wages had been established. For instance, the average output per worker increased 10.2% in 1949 and the average wage increased by 5.7% over 1948. In 1950 labor productivity increased 7.9% and the average wage 1.8% over 1949.

In the fifth five-year plan the increase in labor productivity outstripped the increase in wages. During the fifth five-year plan labor productivity increased 64.1% while wages increased 18% which was one of the factors making for a reduction in production costs in the aluminum industry.

At the Ural Aluminum Plant, starting with 1942, the rate of growth in the average wage outstripped the rate of growth of labor productivity which led to an increase in the portion of the cost of one ton of aluminum due to wages (Table 19).

At the Stalin Aluminum Plant, as at other plants, in 1945, 1946 and 1947 the increase in labor productivity, lagged behind the increase in wages (Table 20). (See Table 19 and 20 on following page.)

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TABLE 19

CHANGES IN LABOR PRODUCTIVITY AND AVERAGE WAGES AT THE URAL PLANT

Index	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Average output per worker in: % of 1940	100	177.2	155.5	156.2	179.0	180.0	157.2	187.4	201	206	226
% of preceding year	100	177.2	87.7	100.2	114.8	100.6	87.4	119.1	107.5	102.4	109.6
Average wage per worker in: % of 1940	100	105.4	106.5	120.0	148.0	168.7	177.2	216.5		[illegible]	[illegible]
% of preceding year	100	105.4	101.1	112.6	124.7	115.4	102.7	122.3	108.0	105.7	101.3

TABLE 20

CHANGES IN LABOR PRODUCTIVITY AND AVERAGE WAGES AT THE STALIN PLANT

Index	1943	1944	1945	1946	1947	1948	1949	1950
Average output per worker in: % of 1943	100.0	140.0	171.7	161.0	133.0	145.8	164.0	188.8
% of preceding year	100.0	140.0	122.2	93.9	76.4	118.5	112.4	112.1
Average wage per workers in: % of 1943	100.0	124.0	153.0	155.0	189.3	220.0	218.8	220.3
% of preceding year	100.0	124.0	123.5	101.3	112.1	116.2	99.5	100.7

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In 1946 and 1947 labor productivity decreased at almost all aluminum plants in connection with the reconstruction of electrolytic sections and the transition to the normal work day.

Only at the Bogoslovskoye Aluminum Plant was there a favorable ratio between the increase in labor productivity and wages. Labor productivity (with the exception of 1947) increased at a more rapid rate than average wages.

At individual aluminum enterprises the rate in the increase in wages surpassed the rate of increase in labor productivity which was the result of the failure to utilize all the numerous potentials and the use of practical-statistical standards in auxiliary divisions, a different type of supplementary pay and unprofitable scales of progressive and bonus payments.

An analysis of the wage level in basic divisions over a number of years has shown that among workers in the basic production divisions the highest wages were received by workers in electrolytic sections.

Among basic production workers in the basic divisions the additional pay was small by comparison to the base pay (with the exception of electrolytic workers). Among auxiliary workers in the basic divisions and the repair section additional pay was almost equal to base pay which was the result of a lack of intensity in production standards and a related high degree of overtime.

In the alumina plants repair personnel received higher wages than workers in basic production which was the result of poor judgement in establishing standards for repair operations (lack of standards based on operations, pay on the so-called no-category system and bonuses of 30% of the base pay for meeting the equipment repair schedule and breakdown-free operation of machinery units). The actual staffing of repair brigades was actually below what was planned which also contributed to increasing their individual earnings.

As the result of a marked increase in the average earnings of workers, the wage funds in the aluminum industry increased constantly and surpassed the rate of growth in the number of employees caused by the expansion of the volume of production.

The growth in wage funds was accompanied by a change in their structure: there was an increase in the amount of progressive and bonus payments and payments for years of service, there was a decrease in the proportion of payments on a time basis at the expense

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of an increase in the progressive piecework system of pay, and payment for overtime was reduced greatly.

The structure of the wage funds by different plants in 1956 is illustrated in Table 21.

TABLE 21

RATIO OF DIFFERENT TYPES OF WAGES IN THE TOTAL FUND AT ALUMINUM PLANTS IN 1956 IN % OF THE TOTAL FUND

Type of payment					
Payment by base piece rate for straight piecework	35.3	43.8	21.7	41.7	38.6
Payment by base piece rate for progressive piece-work	21.99	6.17	32.3	5.19	19.6
Supplementary pay for piece-workers on progressive rates	4.6	1.5	7.3	1.5	2.3
Payment on time basis according to base pay rates	19.3	19.1	14.57	10.3	11.4
Bonuses to pieceworkers	1.2	4.85	0.6	7.6	6.2
Bonuses to workers on time basis	1.4	5.5	3.2	2.7	6.6
Overtime pay	0.01	0.02	0.03	0.01	0.05
Other supplements making up the daily wage fund	5.4	4.26	4.0	14.6	1.4
Other supplements making up the monthly wage fund	6.6	7.3	7.3	11.1	7.5
Compensation for length of service	4.2	7.5	9.1	5.4	6.35
Total wage fund	100	100	100	100	100

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The organization of wages in the aluminum industry has great possibilities for increasing its role in stimulating growth in labor productivity; this requires raising base pay rates and a radical revision of the base pay tables in order to eliminate the equalizing tendencies in their structure as well as to eliminate the multiplicity of rate tables by creating a uniform base rate system for the entire aluminum industry and it requires a uniform bonus system for workers in any one occupation working under analogous conditions at different enterprises;

establishing standards and rates on the basis of a technological evaluation in accordance with the rising level of technology and achievements of leading workers and innovators;

improving the standards system for auxiliary operations in basic and auxiliary divisions in order to include more workers in the piecework system and eliminate overpayment resulting from insufficiently demanding standards of production leading to a levelling of pay between workers in key occupations and auxiliary workers;

developing a bonus system for workers on a time basis based on a consideration of the quality of work and peculiarities of specific individual occupations.

A revision of the wage system will make it possible to employ it more effectively to further a growth in labor productivity in the aluminum industry.

Raising the base pay rates will make it possible to make the base pay the greater part of earnings and create favorable conditions for an extensive introduction of technically based production norms, the elimination of a fictitious piecework system and the eradication of economically unjustified incentive systems.

9. Socialist Competition and Progressive Work Methods

Socialist competition is a powerful source for increasing labor productivity.

The great force of free creative labor in a socialist society is clearly expressed in the diverse forms of socialist competition and to the mass movement of leading workers and innovators.

Mass socialist competition, the development of popular initiative and independent activity are a clear expression of vital Soviet patriotism, the source of the historic successes of the Soviet people.

The movement of leading workers and innovators expresses a new and higher stage in socialist competition connected with the adoption

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of new equipment in all branches of the national economy and the appearance of new people who have completely mastered the complicated equipment.

The Communist Party and the Soviet government have been giving great attention to developing socialist competition and require from economic, Party and trade-union agencies the elimination of shortcomings in the development of creative initiative and productive activity among the masses of workers. The administration of socialist competition must not admit a routine, formalistic or bureaucratic approach to new progressive manifestations of initiative on the part of the workers.

Groups in all enterprises of the aluminum industry are participating in socialist competition aimed at meeting and exceeding production plans, at increasing labor productivity, production quality, at reducing production costs and improving other very important technical and economic factors.

Along with individual competition there has been widespread adoption of competition between shifts, sectors, divisions and entire plants. At the same time all establishments within the aluminum industry are also taking part in All-Union Socialist Competition.

Winners in competition between sectors and brigades are awarded each month the challenge Red Banners of the plant or mine and the retention of these banners for three months in a row means cash bonuses from the funds of the enterprise.

Winners in competition among workers in the same occupation and groups of brigades, shifts and sectors for three months in a row are given the title "Best Worker in the Occupation", "Best Brigade", "Best Shift", "Best Sector."

Leading workers employ the following diverse type of work methods:

division of labor in which it is possible to make maximum assignment to each worker on the basis of his knowledge and training;

reduction of idle time and idling of machinery and increasing the efficient use of equipment on the basis of a complete study of mechanisms, apparatus, technological processes and mastering production techniques in their own sector;

improving technical processes, introduction of on-the-spot improvements of an uncomplicated nature to facilitate operation;

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combining related jobs and serving a large number of machines, tools and apparatus;

better organization of the working site;

improving tools, setup methods and parts machining (change in the shape of the cutting tool, drill, etc.);

improvement in labor organization (efficient distribution of the labor force, organization of mixed brigades);

combining the maintenance of different production sectors and freeing unnecessary labor forces;

assuring harmony in the operation of separate production units and sectors;

introducing hourly and shift-day work schedules;

competition for outstanding production quality and a high level of production;

creating mixed brigades of inventors and efficiency promoters.

An important feature of socialist competition during recent years has been the national movement for making a better use of internal production potentials, strict economy, general saving of materials and the creation of accumulated stocks in excess of the plan; for getting the maximum production from existing equipment and production areas; for accelerating the turnover of working capital; for introducing the best work methods of leading workers and innovators and the adoption of these methods by all workers; for meeting the production assignment of each shift.

The movement of leading workers and production innovators has become widespread in all establishments in the aluminum industry.

The number of competing workers at aluminum plants and bauxite mines is increasing from year to year. In order to attract a large number of workers into socialist competition socialist agreements have been drawn up between brigades, sectors, mines, divisions and individual agreements between individual workers, and production conferences have been arranged between leading workers and innovators at which leading methods are studied and analyzed from the point of view of general application.

The creative initiative of workers in production is constantly giving birth to newer methods of labor organization.

As an example of progressive methods in drifting operations we have the work of mixed brigades engaged in high-speed drifting operations.

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The speed of opening operations in mining are of particular importance and for this reason problems in the organization of drifting operations were given a great deal of attention during the very first years of the exploitation of the deposits of the Northern Ural Bauxite Mines.

Up till 1943 the rate of drift opening at the Northern Ural Bauxite Mines did not exceed 20-30 linear meters per month. Starting with 1943 high-speed drifting was organized and carried out by mixed brigades. Engineers and technicians of the Northern Ural Bauxite Mines took an active part in carrying out high-speed drifting operations.

Tunnelers (drift workers) Minzaripov and Pronichkin were winners of the Stalin Prize.

As we can see from the data cited below, during the very first high-speed drifting operation organized in 1943 by Sabirov's brigade a rate was achieved exceeding 2.5 times the usual drifting rate at the Northern Ural Bauxite Mines.

The principal condition which made this high-speed possible was simultaneous performance of basic drifting operations (drilling, timbering, clearing out rock). The combination of operations made possible three cycles in each 24 hours.

Although drifting speed increased 2.5 times over the usual rate, it could have been still higher. Drifting was being done while builders were putting the mine into operation so that there were standstills in supplying compressed air. In addition, members of the high-speed brigade were still inexperienced in the operation.

Nevertheless the results obtained by Sabirov's brigade served as a turning point in the further improvement of high-speed drifting. Other brigades began to follow Sabirov's example.

In 1944 Simagulin's brigade composed of 15 men (5 men per crew) reached a drift rate of 90 linear meters. The rate was increased by compressing operations in the cycle.

In 1945 Sosayev's brigade made one stope 162.4 linera meters long. As distinct from previous drifting operations this was done in 4 shifts. Five men worked in each shift. One cycle of drifting operations was done in each shift. Thus the number of cycles was brought to four.

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Starting with December 1945 loading machines were used in high-speed drifting to accelerate the removal of the mass of loose rocks.

In 1946 Minsaripov's brigade made a drift 172 meters long. In addition to using loading machines for rock removal there was the new feature of using deeper blast holes than in previous operations.

In Table 22 we have the technical and economic features of high-speed drifting operations at the bauxite mines in 1943-1956.

The best results in high-speed drifting were achieved in subsequent years. As we see from the data cited in Table 22, the depth of the blast holes was again reduced in 1956 but high indexes were produced thanks to the use of more powerful explosives and a more efficient placement of blast holes, to the constant improvement in labor organization, the increased use of machinery in the drifting cycle, and the use of improved equipment. Another feature of high-speed drifting operations in 1947-1956 was the adoption of multicycle work. For example, 155 cycles were carried out in drifting in October 1947, 171 in March 1948 and 251 in February 1956. This increase in the number of cycles was achieved through a further compression of drifting operations and their simultaneous performance.

Further success in high-speed drifting operations was also furthered by the use of electric locomotive transportation which replaced the earlier manual operation.

As we see from the data in Table 22, the increase in speed was also accompanied by an increase in labor productivity and the productive capacity of the loading equipment. Labor productivity in drifting quadrupled from 1943 to 1956.

There was also a considerable increase in the productive capacity of the loading equipment. The proportion of mine opening operations effected through high-speed methods at the Northern Ural Bauxite Mines increased constantly throughout the fifth five-year plan which made possible increased speed in tunneling throughout the mines. The proportion of mine-opening operations carried out by high-speed methods increased from 35.7% in 1950 to 59.3% in 1955.

The average monthly rate of gangway opening increased 74.8% from 1952 to 1955 (average speed in 1952 was 36.9 linear meters and in 1955 it was 64.5 linear meters per month) while the average monthly rate of inclined workings during this period more than doubled (22.7 linear meters in 1952 and 48 in 1955.).

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It is necessary to point out the following very important factors which determined the possibility for high-speed mine-opening operations.

TABLE 22

TECHNICAL AND ECONOMIC FEATURES OF HIGH-SPEED DRIFTING OPERATIONS DURING THE PERIOD 1942-1956

Year	1943	1944	1945	1946	1947	1948	1949	1950	1956
Monthly advance of stope in linear meters	73	90	162.4	172	181.4	203.4	254	268.6	302
Cross section in square meters	8	8.5	8.5	8.59	9.18	8.90	9.9	9.9	9.5
Timbering on the Pretod'yakonov scale	5-6	5-6	6-8	6-8	6-8	6-8	7-9	7-9	6-8
Number of blast holes per stope	18	18	23	22	26	18	--	--	27
Average depth of blastholes in meters	1.13	1.25	1.63	1.87	1.44	1.49	1.66	1.79	1.4
Average consumption of explosives per cu. meter of rock, in kilograms	1.9	1.95	2.05	3	1.93	1.347	--	--	1.73
Method of rock removal	Scraper	Scraper	Loader	Loader	Loader	Loader	Loader	Loader	Loader
Advance of stope per man/shift in linear meters	0.163	0.187	0.262	0.278	0.313	0.349	0.450	0.496	0.361
Number of cycles per month	82	87	119	121	155	171	184	174	251
Labor productivity of drift worker in shift in cu. meters/hour	1.3	1.5	2.23	2.36	2.86	3.15	4.48	4.74	5.15

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1. Total mechanization of difficult processes: drilling by boring machines, clearing by loaders, timbering brought to inclined drifts by pneumatic winches, cars drawn along drifts by electric locomotives and on the surface by pneumatic winches, cars switched by pneumatic car movers.

2. Operations on a cyclic production schedule based on simultaneous operations.

3. Correct organization of wages for drift workers and service personnel.

4. Prompt delivery to drift workers of all necessary material and tools thanks to detailed preparation of all drifting operations.

As an example of progressive work methods in extraction we have the work of mixed brigades and mixed crews in high-production blocks.

After August 1947 mixed brigades started operating in high-production brigades at different mines which was an important factor in increasing labor productivity in extraction operations.

Mixed brigades achieved very good results. The productivity of the mining block increased 2-3 times.

Labor productivity of the stope worker also greatly exceeded the normal.

In 1955 at the Northern Ural Bauxite Mines there was an average of 34 high-production blocks in operation.

Labor productivity of stope workers of leading brigades exceeded the mine average by more than 1.5 times (4.55 cubic meters/man/shift and 2.8 cubic meters/man/shift).

Thus work in high-production blocks was characterized by the following factors:

mechanization of production processes

maximum utilization of work time

operation on a planned cyclogram

presence of a permanent working site and increased skill of stope workers

total use of the stope group of workers in basic production

maintaining tools in good condition

providing the stope brigade with a line of reserve stopes as a guarantee against unforeseen accidents and the inoperability of stopes for geological reasons

the use of incentive wage systems for exceeding production standards and the job assigned.

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At aluminum plants competition by occupations has been widely adopted. For instance individual electrolytic section workers, anode operators, autoclave operators, decomposer operators, roasters, mixer operators, mechanics, machinists, forgers and others have been in competition.

Competition conditions have been worked out for each profession and for separate sectors.

On the basis of individual obligations groups of plants have assumed obligations toward the government to increase production, to complete the state plans ahead of time, to increase labor productivity, to reduce production costs and to accumulate stocks in excess of the plan.

Most extensive has been the movement of leading production workers at aluminum plants in the form of general improvement in production techniques and organization.

The movement of leading workers and innovators in electrolytic sections divisions leads to exceeding production standards, to increasing output (on the basis of current, energy and cell-day), to savings in electric power, alumina, fluorine salts and other materials and to the production of better-grade metal.

For instance, Petrov's brigade (Ural Aluminum Plant) produced 93.6% better grade aluminum, including 82.5% of A-00.

The methods which assured Petrov's brigade this success are the following: the brigade worked with cells with thick side and bottom crusts. The thick side crusts prevent current leaks and the contamination of metal by admixtures from the side lining. Incrustations by compressing the metal raise its level and a high level of metal is an important factor which determines stable and cold operation of the cells which is necessary for producing high-grade metal.

In Petrov's brigade the cells operate on the cold process, the temperature of the electrolyte does not exceed (with rare exceptions) 950°. The average operating voltage of the cells does not exceed 4.2 volts.

The top level of the metal in the baths is maintained at 20-25 centimeters after tapping.

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Anode effects have a great effect on the temperature of the bath. The average number of effects per bath per 24 hours was 0.47 or an average of 1.88 between tappings (i.e. 4 x 0.47 equals 1.88).

The anode effects remain no longer than 5-6 minutes in order to avoid overheating the electrolyte and losing electric energy.

Overheating of the electrolyte during the anode effect is not permitted. The effect is extinguished by a wooden rod. The cells do not remain damped but are completely overhauled. The foam is carefully removed from the electrolyte.

In order to assure good cell maintenance in all shifts, the brigade leader attempts to distribute the work load between shifts as evenly as possible.

The average number of overhauls per shift is 3.5 (with and without anode effects).

When the raw material is being charged the brigade sees to it that impurities with recirculating electrolyte and foam do not get into the cell. The brigade checks the operation of the anode operators in order to avoid the falling of iron and copper scale into the bath when the contacts are being cleaned.

A large amount of alumina is dumped in for 16-18 hours of cell operation. The alumina is sprinkled in evenly over the entire surface of the crust after the cell has been worked over.

Cryolite and aluminum fluoride are sprinkled onto the electrolyte crust (under the alumina) after the bath has been worked over. In order to maintain a high quality of the metal, electrolyte losses are most frequently compensated for by liquid electrolyte refined in the master cells.

Progressive work methods in electrolytic divisions are based on establishing specific parameters of alkalinity of the electrolyte, a specific level of metal following tapping, in maintaining a constant temperature in the cells during hot and cold periods, in establishing an exact order for servicing the baths (working over cells after anode effects, charging the alumina, preparing cells for tapping, prevention of anode effects).

Leading technical workers master related auxiliary occupations which makes it possible to reduce the number of auxiliary workers

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in the basic divisions and improve the condition of the equipment inasmuch as workers in the basic occupations have the greatest interest in the good operation of the equipment which they are maintaining.

These progressive methods of labor organization have become widespread in the alumina sections which has made it possible to reduce the number of attending personnel.

At all aluminum plants a study is being made of the work of leading brigades and on the basis of a general analysis of their experience instructions are worked out concerning progressive methods for servicing the electrolyte cells and other units. For example, in 1956 alone, on the basis of studying and analysing progressive work methods at the Dneprovsk plant, material was published which provided for a general application of an up-to-date electrolytic process with a minimum cryolite percentage of 2.2-2.5; work practices of anode operators Fedorov and Los' in shifting and cleaning bar-pin contacts; the practice of anode operators Shatilov and Razuvanov in pulling pins from the anodes of electrolyte cells with the S-2 pneumatic apparatus; the practice of leading brigades of Comrades Machurashvili, Popravok and Grushetskiy in introducing up-to-date techniques and organization of labor.

At the Stalin Aluminum Plant in 1956 studies and analyses were made of up-to-date work methods of brigades under Demidov and Mosikevich, modern work practices of anode operator Sosyatkin; his method is now being introduced among anode operators and the Shornikov brigade's modern methods in casting wirebars has already been put into operation. As a result of the introduction of this method among wirebar casters, production quality has improved, waste has been reduced and it has become possible to cast two tons per hour instead of the previous 1.5 tons.

In alumina sections of the Ural Aluminum Plant the study of progressive practices and the selection of the best work methods has resulted in instructions on progressive methods for working with evaporating apparatus, thickeners and mills. The instructions on the operation of mills included an application of the method of Comrade Tarabukin who determined that continuity in the operation of mills is a most important condition for maintaining constancy of the given cycle. Characteristic of his method is a strictly determined order for carrying out operations in maintenance which assures systematic inspection and strict control over the course of the technical process.

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In 1956 a study was made followed by the introduction of up-to-date practices of operators of primer hydrate filters which made it possible to establish more advanced technological conditions for filtering primer hydrate, to increase the productivity of the filters and improve the quality of the filtrate.

The work of brigades in the soda caustification section has also been adopted generally.

Most widespread has been the combination of jobs among auxiliary workers in the basic divisions: the mechanic is also a forger, the electric welder is also a gas welder, the forger also works with sheet metal, the lathe operator is also a milling machine operator, the scales operator is also a crane operator.

Leading workers in machine repair employ in their work methods used in servicing many machine tools (work on two vertical lathes). However, the possibility of operating several machine tools is limited by the individual nature of operations to repair shops of aluminum plants (dissimilarity of spare parts and attachments being made).

In all enterprises engineering and technical personnel have taken an active part in studying, analysing and transmitting progressive practices.

At mines and plants of the aluminum industry a large army of innovators has sprung up which demonstrates examples of progressive work methods and whose names are known not only at plants in the aluminum industry but beyond its confines: drift brigade leaders Minasripov and Safutin, stope brigade leaders Iguts, Shokk, Chervatyuk (Northern Ural Bauxite Mines), Mikhalev, Kuznetsov (Ural plant) Kovylyayev, Syutkin (Bogoslovskoye plant), Mogutov, Vysotskiy, Karabanov(Volkhov plant), Popravka (Dneprovsk plant) and others.

The decisions of the Twentieth Congress of the CPSU pointed out the necessity for an all-round extension of the mass movement of efficiency promoters, inventors and innovators as well as for assuring extensive publicity and introduction of up-to-date practices.

During recent years the movement of inventors and efficiency promoters has become widespread at enterprises in the aluminum industry. There has been acceleration in studying proposals submitted by efficiency promoters; photographic exhibits of the best efficiency promoters and their proposals have been organized; the best proposals have been given systematic publicity in the local and factory press; monthly enlarged sessions of shop committees consider achievements

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with the awarding of first places for the best evidence of efficiency promotion in the enterprise; there is a quarterly summing up of efficiency work at all-factory meetings of efficiency promoters; "bottle necks" in mines, shops and separate plants are analysed and pointed out to workers.

Participation by workers in efficiency promotion in plants has greatly increased. For instance, at the Ural plant the number of efficiency promoters in 1956 was 851 as against 756 in 1955; at the Tikhvin plant 743 in 1956 as against 326 in 1955; at the Kanaker plant 180 in 1956 as against 144 in 1955; at the Volkhovskoye plant 470 in 1956 as against 392 in 1955. The number of suggestions adopted and their economic effectiveness has also increased (Table 23).

TABLE 23

GROWTH IN THE NUMBER OF EFFICIENCY PROMOTION SUGGESTIONS AT ALUMINUM PLANTS IN THE PERIOD 1955-1956

Plant	Year	Received	Adopted
Ural Aluminum	1955	1467	692
	1956	1496	783
Tikhvin Alumina	1955	383	190
	1956	1134	639
Sumgait Aluminum	1955	89	34
	1956	150	94
Kanaker Aluminum	1955	315	173
	1956	420	231
Volkhov	1955	676	297
	1956	782	381

The adoption of efficiency promotion suggestions contributed to improving the operation of equipment, reduced standards for the consumption of raw and processed materials, lightened labor and reduced production cost.

For instance, at the Ural Aluminum Plant there was a nominal yearly saving of 4335 rubles in 1956 from 377 suggestions alone.

Economies in raw and processed materials and power from proposal adopted consisted of:

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Electric power	3,600,000 million kilowatt hours
Steam	56930 megacalories
Caustic	352 tons
Bauxite	88,000 tons
Ferrous metals	336 tons

At the Dnepr Aluminum Plant the nominal yearly savings from 156 adopted efficiency proposals was 2748000 rubles in 1956 including 228,000 rubles in raw materials, 321,000 rubles in metal, 66,000 rubles in electric power, 880,000 rubles in wages by reduction in the labor force, and 532,000 rubles in fuel.

At the Kanaker Aluminum Plant the nominal yearly savings figured on the basis of 30 adopted efficiency proposals amounted to 1,192,200 rubles in 1956.

Consolidating and improving forms of socialist competition, analyzing and making available to all the valuable experience of leading workers, encouraging initiative in all ways, raising laggers to the level of leading workers, using every means to extend the mass movement of inventors and efficiency promoters and innovators, all this constitutes one of the most important goals of workers in the aluminum industry.

A major role in the further development of the movement of leading workers and innovators is played by the creative cooperation of workers in science and production based on the joint work of Soviet scientists, leading workers and engineers. This cooperation helps workers in industry to better utilize the achievements of modern science and helps scientists to enrich science with the practice and experience of leading workers.

The Central Committee of the CPSS and the Council of Ministers of the USSR in a decree of August 7, 1958 "On the Conversion to the Seven-and Six-Hour Work Day and the Regulation of Wages in the Non-ferrous Metal Industry" pointed out that carrying out measures on adjusting wages with a simultaneous reduction in the length of the work day is inseparably connected with the necessity for improving the utilization at all enterprises of all available potentials, for strenuously adopting up-to-date practices, new equipment and modern technology, for keeping equipment at more nearly full operation, and for improving industrial and plant management.

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The observance of the principle of tying wages in with a constant increase in the production of nonferrous metals, the growth in labor productivity, the improvement in quality and reduction in production costs must be the daily concern of managerial, Party and trade-union organizations.

CHAPTER IV

PRODUCTION COSTS IN THE SOVIET ALUMINUM INDUSTRY

1. Factors in the Reduction of Production Costs in the Aluminum Industry

Production cost is a most important indication of the quality of operation of an industry, its branches and individual enterprises. This indication expresses the level of consumption of labor represented by living persons and material in enterprises and branches of industry per unit of production. It reflects the level of technology and production organization, the efficiency and economic effectiveness of the use of equipment, labor force, raw and processed materials, fuel, electric power, loss control and unproductive expenditures, the efficiency of the raw material supply, and cooperation. An unvarying reduction in expenditures per unit of production, its cost and production cost are most important factors which characterize the degree of profit in the operation of an enterprise.

A necessary condition for solving the magnificant objectives in the development of a Communist society is the continuous growth of accumulated capital used in expanding socialist production. A reduction in production cost at enterprises of the Soviet aluminum industry contributes to increasing accumulations within the industry, and leads to a reduction in overall production expenses in the production of aluminum and its alloys with the result that there is a reduction in selling prices and conditions are created for a still greater use of aluminum in the various branches of industry where the previous high price of aluminum had limited the range of its utilization.

In this connection a study of production costs at enterprises of the aluminum industry is of great interest for it makes it possible to detect the basic factors which determine the level of production costs and to discover possibilities for a reduction.

Among the diverse factors which effect the production cost level the principal ones are: a growth in labor productivity to

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exceed the growth in average wages; a reduction in the mean consumption of raw and processed materials, fuel and electric power; improvement in the utilization of waste products; a reduction in long-distance transportation of production tools and finished products, the utilization of local resources, improvement in the utilization of fixed assets; a reduction in administrative and trade costs and the elimination of unproductive expenditures.

In various branches of the industry the role of the different factors governing the reduction in production cost is not the same and depends on the structure of production expenditures. For the aluminum industry which includes mining enterprises, the production of fluorine salts, electrodes, alumina and metallic aluminum, all the factors mentioned above are important but the degree of their effect on production cost is determined by the structure of expenditures in the different production processes of this branch of industry. A characteristic feature of the aluminum industry as a whole is the great consumption of power in the production of aluminum. This is reflected in the structure of the aluminum prime cost where expenditures on electric power constitute 15-30% of the cost price. The specific proportion of power expenditures (steam, fuel, water, electricity) in the cost price of alumina is approximately 24-28%.

At mining enterprises a decisive factor in the reduction of prime cost is the growth in labor productivity which is achieved largely through mechanization of extraction processes and the selection of more effective systems for exploiting the deposit under the mining and geological conditions prevailing.

The level of the prime cost as well as the structure of expenditures at enterprises of the aluminum industry turning out the same product are not identical. They depend on the technological level, technical systems and the equipment in use, the specialization and cooperation system of the enterprises, the degree of utilization of production tools, the size of the enterprises and the distance involved in the delivery of raw and processed materials.

During the period of 1940-1950 there was an increase in the prime cost of raw material for aluminum of 49%. But this increase in the prime cost does not reflect the real increase in aluminum production expenses since a variation in the wholesale prices for raw and processed materials, railroad rates and pay scales makes it impossible to compare the production cost for individual years.

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A correction has been made for the 1950 production cost by individual plants in accordance with conditions for the base periods and this showed that the production cost of one ton of raw aluminum in 1950 was 5.2% less than the prewar level at the Ural Plant, 2.7% less at the Volkhov plant and 17.4% less at the Bogoslovskoye plant.

In 1947 and 1948 the aluminum production cost at the Ural plant was reduced. In 1949 production cost at enterprises in the aluminum industry increased over preceding years in connection with higher wholesale prices for raw and processed materials, fuel and electric power rates.

By conversion to 1948 prices the 1949 production cost was 1.3% less at the Ural plant, 4.3% less at the Volkhov plant, as well as at the Stalin and other plants.

During the period 1947-1950 production cost was reduced through increasing the volume of production, reducing the consumption of raw and processed material and electric power. During the fourth five-year plan as a whole the production cost of raw aluminum (in terms of comparative prices) dropped 11.8% at the Ural plant, 12.7% at the Stalin plant and 17.4% at the Bogoslovskoye plant.

In 1946-1947 at the Stalin Aluminum Plant the increase in the aluminum production cost was caused by wear on the cells with oval shells which had been installed during the war years which, in combination with an irregular electric power supply, led to overconsumption of raw and processed materials and electric power and to a lower level of labor productivity. In 1948-1949, following the replacement of oval by rectangular shells, labor productivity increased, the consumption of material and electric power decreased and the cost of aluminum was reduced.

Following reconstruction at the Volkhov plant the cost of aluminum dropped from 1946 to 1948 but rose in 1949 as the result of higher wholesale prices as well as the utilization of its own alumina from nephelines, the production of which was only then being adopted.

The lowest aluminum production cost was at the Ural Aluminum Plant.

Alumina is the basic intermediate product of the aluminum industry. Expenditures on alumina make up 35-40% of the production cost of raw aluminum.

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Conversion to processing Northern Ural bauxites by the Bayer method brought on a sharp reduction in the production cost of alumina in 1941-1942 as against the prewar period when bauxites from the Tikhvin deposits were being processed.

The production cost level for alumina was lower in 1945 than 1940 when Tikhvin bauxites were extensively used at the Volkhov, Dneprovsk and Tikhvin plants. The conversion of the aluminum industry to operating with Northern Ural bauxites contributed to a reduction in the production cost of alumina below the prewar level.

For instance, in 1948 the cost of producing one ton of alumina was 22% less than in 1940.

Comparative data on the cost of producing one ton of alumina at plants during the period 1940-1950 are given in Figure 3.

The increase in the production cost of alumina in 1949 and 1950 was due to higher wholesale prices and not production expenditures. The production cost of alumina in 1949 dropped 7% below 1948 at the Ural plant and 29% at the Bogoslovskoye plant. At the Ural plant alumina production cost was 15.5% lower in terms of comparable prices in 1950 than 1941 and during the fourth five-year plan alumina production cost at this plant dropped by 24.5% of the 1945 level.

Alumina production at the Bogoslovskoye plant did not become a normal operation until 1946 after which there was a constant reduction in prime cost.

For instance, the adoption of up-to-date methods during and after the war contributed to a reduction in the production cost of alumina and consequently in the production price of aluminum.

A second most important factor in reducing aluminum production costs was the conversion of electrolytic plants to cells with a single self-baking anode operating on higher current instead of the low current (29-34 kiloamperes) used by multianode cells during the prewar years.

A change in the design of electrolytic cells contributed to reducing the unit consumption of electric power and the basic materials and to a growth in labor productivity in the aluminum industry.

During the fifth five-year plan there was a further reduction of 30.5% in the cost of production in terms of comparable prices with the cost of one ton of aluminum dropping 22.4% at the Ural plant,

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32.7% at the Stalin plant, 39% at the Volkhov plant, and 43.2% at the Dneprovsk plant while at the Kanaker and Kandalaksha plants production cost in 1955 was one half that of 1955.

The cost of producing one ton of alumina dropped 29.2% at the Ural plant and 52.1% at the Bogoslovskoye plant. At the Volkhov plant the cost of producing one ton of alumina had been 6.6 times greater in 1950 than 1956, reduction resulting from the adoption of the over-all processing of nephelines.

This made it possible for the government on June 1, 1955 to reduce then current wholesale prices for aluminum which is now cheaper than copper and lead. The wholesale price of aluminum was 107% of the wholesale price of copper in 1940 and 86% in 1956, with respect to zinc it was 289% and 144% respectively, with respect to lead 345% and 69%.

Thus during the past 15 years the reduction in the production cost of aluminum has advanced more rapidly than the reduction in the cost of copper, zinc and lead.

Up to 1935 the output of aluminum at the best aluminum plants did not exceed 50 grams per kilowatt hour. In 1940 this ratio increased and at present individual aluminum plants have reached an output of 60-62 grams per kilowatt hour.

In 1956 the lowest consumption of electric power in electrolytic cells with self-baking anodes was obtained at the Kanaker Aluminum Plant (16427 kilowatt hours per ton of aluminum) as well as at the Kandalaksha, Dneprovsk and Nadvoitsy plants.

2. Cost of Bauxite Extraction at the Northern Ural Bauxite Mines

Expenditures on bauxites constitute 17-25% of the cost of alumina and 7-10% of the production cost of aluminum.

Up to 1948 the working of deposits of the Northern Ural Bauxite Mines took place simultaneously by open-pit and underground method, the ratio between them being an important determinant factor of the level of cost of extracting bauxites in the mines (Fig. 4).

Data given in Fig. 5 illustrate changes in the all-mine cost at the Northern Ural mines as a whole during the period of 1941-1950 and by open-pit and underground mining in comparison with the proportion of underground work in total extraction.

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With the increase in the percentage of underground operations the cost price of bauxites increased. During the period 1941-1950 the cost of bauxites at the Northern Ural Bauxite Mines more than doubled.

The increase in the production cost of bauxite was caused not only by the increased proportion of underground operations but by the absolute increase in the cost of bauxites in both open-pit and underground operations.

During the period from 1941 through 1947 the cost of bauxites increased constantly, reaching in 1947 153% of the 1941 level for open-pit mining and 196% for underground extraction. Since 1948 the production cost has declined as the result of a marked increase in labor productivity connected with mechanization, the extension of modern methods and the reduction in the volume of mine-opening operations (working out the upper portion of the deposit).

The increase in production costs in open-pit and underground operations has both common causes and those specific for each type of operation.

Among the causes of a general nature are: increased cost of timbering and explosives, increase in average wages (in connection with the pay rate reform of 1944 and 1946 on the basis of the government decree increasing the wages of workers in the Urals, Siberia and the Far East and the increase in wages at the end of 1947 aimed at equalizing the wages of workers at the Northern Ural Bauxite Mines with those of workers of the Far North).

The increase in the average wage caused a marked increase in production cost in mining enterprises where the structure of production costs is characterized by the large percentage of expenditures for labor. In the cost price for extracting bauxites at the Northern Ural Bauxite Mines the proportion of expenditures on the pay of production workers alone is 20%. The increase in wages is an increasingly expensive factor for the so-called nominally constant expenditures, divisional and all-mine, which include items such as wages as an element of expense.

The shift to more complex mining conditions caused an increase in expenditures for mine opening operations and increased the amount written off as production cost and caused an increased consumption of material and labor.

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Since 1947, despite the increase in the average wage, the amount of the item "wages of production workers" has diminished, thanks to the rapid growth in labor productivity.

The increase in labor productivity was achieved by the extension of up-to-date methods and total mechanization of open-pit operations.

A most important article in the production cost of bauxites in open-pit mining is "paying the cost of preparatory operations" (removal of overburden): this makes up 50% of the production cost.

The increase in expenditures for opening operations, pointed out for 1944, had a great influence on raising the general production cost level.

Thus the principal causes in the increase in bauxite cost in open-pit operations were the higher cost of mine opening operations under poorer mining conditions and an increase in the amount spent to pay for the preparatory operations.

The cost of bauxite in open-pit operations increased 70% from 1941-1950.

The change in mining conditions was an important factor in increased production cost. In 1941 only the upper horizons of deposits were being mined, i.e. above the level of underground waters.

The shift to the lower horizons caused additional expenses in increasing the volume of mining operations and in mine drainage. In addition, the greater hardness of rocks in the lower levels increased the consumption of electricity, explosives, compressed air and other materials as well as increasing the amount of manpower used.

Wage expenditures approximately doubled. The size of this expenditure was determined by the level of labor productivity and pay rate conditions.

After 1945 thanks to the adoption of an improved system of top slicing as compared with the hitherto employed longwall system and the organization of high-production blocks (1947-1950) labor productivity increased.

In connection with the increasing complication of mining conditions there were increased expenses for preparatory operations. In 1946 they made up approximately 5% of the total expenditures but in 1950 they were more than 15%.

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An important factor in reducing the production cost of bauxites in underground operations was the increase in labor productivity and the increase in the volume of ore extraction.

As early as 1950 the level of bauxite production cost at the Northern Ural Bauxite Mines was determined by the cost in underground operations.

The growth in labor productivity, improvement in the mining system, mechanization of production processes, adoption of up-to-date methods in the organization of production and labor assured a reduction in bauxite production cost at all mines of the aluminum industry.

In 1955 the production cost of one ton of bauxite dropped 7.7% over that of 1950 at the Northern Ural Bauxite Mines, 12.5% at the Southern Ural Bauxite Mines and 42.5% at the Tikhvin Bauxite Mines.

3. Alumina Production Cost at the Ural Aluminum Plant

Of the plants in operation before the war the highest cost of alumina production was found at the Dneprovsk Aluminum Plant and the Tikhvin Alumina Plant.

The high production cost at the Dneprovsk plant was determined by the great expenditures for raw materials through the utilization of bauxites hauled a long distance from the Tikhvin deposits and slags from metallurgical plants.

Tikhvin bauxites are processed into slag in advance in Miguet furnaces. The electrothermal method of producing alumina, employed at the Dneprovsk plant was characterized by great consumption of raw material and of electric power.

In Fig. 6 we have data on the structure of the cost of alumina in plants in existence in 1940-1941.

At the Tikhvin plant expenditures for raw material were lower than at other plants due to the nearness of the plant to the source of supply. All other expenditures, however, were higher which was in part due to the small degree of alumina production at this plant and the less effective sintering method as compared with the Bayer system.

At the Ural plant expenditures on bauxite was one of the most important items in the production cost of alumina (approximately 35%).

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The level of expenditures on bauxites in the cost price of a single ton of alumina has changed comparatively little. There was a sharp increase in expenditures only in 1949 and 1950 in connection with the increase in wholesale prices for bauxites.

There was an absolute increase in expenditures for bauxite only in the period of 1941-1944 after which the consumption of bauxite per ton of alumina decreased.

The reduction in the consumption of bauxite per ton of alumina was accompanied by an increase in the proportion of bauxite at the Northern Ural Bauxite Mines with a higher Al_2O_3 content (51.6-53.1%) and improvement in its detection. The specific consumption of bauxite is determined by the alumina content in bauxite and its extraction.

The extraction factor effects the production cost of alumina not only as an item of expenditures for bauxites but as a nominal constant expenditure since the volume of the extraction determines the utilization of production capacities already available.

All losses of alumina in production at the Ural Aluminum Plant may be divided into the following types:

1. Losses of alumina in leaching, determined by the physical and chemical conditions of the leaching process and the admixture content of the bauxites (principally SiO_2).

2. Losses from hydrolysis. In thickening and washing the red slurry there takes place a spontaneous hydrolytic decomposition of the solution with deposition of alumina hydrate in the red slurry.

3. Losses of alumina in evaporation, i.e. losses with the aluminate solution carried away by barometric water and condensate. These losses depend on the degree of capture of drops of solution carried away by the steam from the separators of the evaporation apparatus.

4. Losses with flue gases from calcination furnaces. The size of these losses depends on the degree of dust recovery in the gas cleaning system.

5. Other mechanical losses. This type of loss includes pulverization of bauxite and alumina, spilling of solutions.

In Table 24 are given data characterizing the amount of alumina losses in production at the Ural Aluminum Plant during the period 1941-1956.

Starting with 1947 losses of alumina in leaching decreased sharply. Other types of loss also declined with the result that extraction increased.

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A basic factor determining the alumina yield from bauxites is extraction in leaching. Losses in leaching depend on the quality of the bauxite and the SiO_2 it contains.

The current standard for bauxites did not foresee the maximum amount of calcium oxide present in bauxites in the form of carbonates.

At the end of 1943 the factory started to receive Northern Ural bauxites with an increased carbonate content which had a bad effect on the management of the technical process.

A second factor determining the degree of leaching is the observation of conditions for cooking in autoclaves. The degree of leaching is directly proportional to the concentration of Na_2O caustic in the by-pass solutions. This concentration depends to a considerable extent on the amount of carbonate soda in the solutions which is formed from the CO_2 of the air and calcites introduced with the bauxites, lime and caustic.

TABLE 24

EXTRACTION AND LOSSES IN ALUMINA PRODUCTION AT THE URAL PLANT IN %

	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1955	1956
Extraction	70.37	68.07	66.58	67.59	70.27	71.74	76.86	79.28	80.82	82.03	86.9	86.5
Losses:												
in leaching	23.15	26.81	26.31	25.03	23.14	20.59	18.10	16	16	15.57	-	-
in hydrolysis	2.36	2.00	1.19	1.51	0.92	1.59	0.47	94	34	-	-	-
in washing	1.29	0.80	0.93	0.95	0.80	0.72	0.55	0.43	0.31	0.76	-	-
in steaming	0.35	0.45	0.47	0.58	0.48	0.43	0.48	0.31	0.30	0.30	-	-
in calcination	1.03	0.60	1.13	1.39	1.89	1.36	0.89	0.84	0.80	0.82	-	-
others and mechanical losses	1.45	1.27	3.39	2.95	2.50	3.57	2.65	2.20	1.42	0.52	-	-
Total losses	29.63	31.93	33.42	32.41	29.73	28.26	23.14	20.72	19.18	17.79	13.1	13.5

During the second half of 1943 and the first half of 1944 the ratio of Na_2O caustic to Na_2O total was 14-15% and the amount of Na_2O caustic in the by-pass solutions was 260-270 grams per liter; in 1945 this factor in Shop No. 1 stood at 10.6-13.8% and in Shop No. 2 at 10-12%.

The excess amount of carbonate soda in the by-pass solutions caused a reduction in the productivity of the evaporation station and increased the consumption of steam in connection with the formation of scales on the heating surfaces of the evaporation apparatuses. The design of the evaporation apparatus was not adapted to operating on solution

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yielding precipitates. The excess amount of carbonate soda had a harmful effect on the grinding of the charge due to the high viscosity of the by-pass solutions. The poorer charge milling and the reduction in the concentration of caustic soda in the by-pass solutions led to a reduction in alumina yield in leaching.

In order to eliminate difficulties in the technical process caused by the high calcite content of the bauxites the following measures were taken:

the Northern Urals Bauxite Mines started preparing different charges with ores from different workings and made a more careful screening of overburden limestone;

in alumina divisions in 1944 the by-pass solutions were heated up in order to separate soda from them and shop causticizers were installed. In addition a special causticizing installed was fitted out.

The separation of excess carbonate soda was complicated by the excessive accumulation in the system of large quantities of organic substances introduced largely with Sokolov bauxites. This caused the formation of instable systems (by-pass solutions supersaturated with soda), which disintegrated under heat and delayed the settling of the separated crystalline soda.

In addition the high organic content of the solutions complicated the washing of the red slurry which caused increased loss of caustic and reduced the concentration of Na_2O caustic in the solutions with the result that there was a reduced yield in leaching (especially in 1943-1945).

As a result of these measures losses in leaching have decreased markedly in recent years.

The reduction in alumina losses was also achieved through improvement in maintaining the production process and carrying out a series of measures aimed at improving separate stages in the technical process. Among these measures were: the introduction of a new method for removing the red slurry from the Dorr washers (gravity chute) which made it possible to take the Dorr Co. pumps out of use, improve the washing of the slurry and reduce caustic losses;

the introduction of a new method for washing the evaporation units making it possible to increase the concentration of by-pass solutions and increasing the productivity of the evaporation station;

improving the grinding of bauxites in Shop No. 2 by the installation of graders in all ball mills;

increasing the revolutions of the mills in order to improve the quality of the grind;

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cutting off scrubbers from the calcination furnaces and the installation of multicyclones (dry gas purification).

In recent years the extraction of alumina from bauxites has greatly increased. Considerable work has been done at the plant in introducing new equipment and improving processes and apparatus, in installing further automatic control and regulation of production processes.

A continuous method has been put into effect for leaching bauxites in autoclaves, the limestone furnaces have been redesigned, filtration of aluminate solution in Kelly sheet filters has been adopted with the use of waste paper instead of binder canvas (block No. 2), hydrocyclones have been introduced for grading bauxite during milling. By partial modernization of alumina calcination furnaces their productivity has increased 28% over what had been planned. Work has been done on over-all automation in grinding (block No. 2) and centrifuging (block No. 1) and new automatic devices have been introduced in various sectors of alumina production.

Increased extraction and the reduction in the unit consumption of bauxite are related to further improvement in the technology and apparatus used in alumina production.

Approximately 25% of the expenditures in the cost price of alumina are due to caustic soda. The material index of this type of raw material is not great. The great proportion of this item of expenditure in cost price is due to the high cost of caustic soda.

In Fig. 7 are data characterizing the variation in the amount of expenditure for caustic soda in the cost price of alumina at the Ural Aluminum Plant during the period 1941-1956.

In 1942-1943 standards for caustic consumption increased due to the sharp increase in the carbonate content of the Northern Ural bauxites.

As the result of an improvement in washing the red slurry (change in the method of removing the red slurry from the washers) losses in NaOH have decreased yearly since 1944.

In 1956 losses of caustic soda had decreased 142 kilograms from those of 1941 which was achieved through the high level of removal of bauxites, reduction in possible overflow, losses of solutions and pulp.

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The reduction in expenditures for raw and processed materials was furthered by the use of slurry produced during the production of alumina.

Red slurry is of practical use in making structural materials such as tiles, clinker, and cement.

Expenditures for steam made up more than 20% of the cost price of alumina. During the war years the increases in steam consumption were connected with difficulties in the operation of the evaporation batteries developing from clogging with carbonate soda and the reduction in heat transmission as well as in additional heating of by-pass solutions in order to eliminate precipitation of soda.

After the adoption of the caustification unit in 1946 the consumption of steam started to decrease.

Improvement in providing alumina sections with steam and better quality of maintenance, stimulated by special bonus payments for savings in steam, contributed to reducing its consumption.

In 1950 there was a further reduction in steam consumption at a pressure of 7 atmospheres by the substitution of separator steam for heating solutions in caustification, expanding the soda caustification unit, and improving milling quality.

During the fifth five-year plan steam consumption was reduced from 6.4 megacalories per ton in 1950 to 5.5 megacalories per ton in 1955.

Wages of production workers with supplements made up approximately 3% of the cost price of alumina.

The increase in labor productivity contributed to reducing the amount of man hours per ton of alumina and the amount disbursed for wages.

Despite the significant growth in the average yearly wages of workers in the alumina section, expenditures for wages took a lesser proportion of the cost of one ton of alumina, thanks to the growth in labor productivity and improvement in production processes and in 1956 were only 76.5% of the level of 1950.

In Fig. 8 are given data describing the change in the amount disbursed for wages for alumina production at the Ural Aluminum Plant during the period 1941-1956.

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Expenditures for production management and maintenance assume a large portion of the cost price of alumina, approximately 14%, including sectional expenditures 11%, and all-plant expenditures 3%. The changes in sectional and all-plant expenditures in producing one ton of alumina are given in Fig. 9.

The increase in expenditures represented in the cost price of one ton of alumina, despite the increase in the output of alumina, was caused by the increase in administrative and managerial expenditures, expenditures for maintenance and others. Simplification of the managerial apparatus and increasing the output later contributed to reducing expenditures for management and maintenance, and sectional expenditures represented in the cost price of one ton of alumina were 38% lower in 1956 than 1950 while all-plant expenditures were 2.5 times greater in 1950 than 1956.

One of the most important sources for reducing cost price is the fuller utilization of production capacities.

A decisive factor in improving the operation of equipment in alumina sections is the organization of timely high-grade maintenance and overhauls. Tardy and faulty repairs lead to rapid machine wear.

The actually greater time between repairs than forseen by the plan has been the result of failure to supply the necessary spare parts, repair material and qualified repair personnel. Faulty repair led to a reduction in the period of operation between repairs and decreased the effective use of equipment.

During the postwar years the coefficient of time of use of equipment increased, the quality of work in maintenance has improved greatly and the cost of repairs has decreased.

Up-to-date repair methods have become widespread. For instance, the repair crew under Comrade Kononov worked out a new system for repairing centrifugal pumps and reduced repair time to one-third.

As the result of the extensive use of modern methods in alumina sections, the better utilization of equipment both with regard to time and capacity, the introduction of new apparatus, intensification and improvement in the technology of separate production sectors, and increasing the skill of maintenance personnel, the output of alumina had increased greatly over 1950 by 1956.

Nevertheless the alumina sections of the Ural Plant still have potentials for increasing alumina production further. In 1956 alone

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alumina production at the Ural plant increased 10.8% over 1955 due to the intensification of operation of autoclaves, thickeners, decomposers and evaporating apparatus. During this period the productivity of the continuous leaching apparatus increased 16.6%, the leaching process was shortened by 0.3 hour and decomposition by 4.8 hours in block No. 1 and 2.7 hours in block No. 2. The amount of alumina produced per cubic meter of decomposer volume increased 0.6 in block No. 1 and 1.6 kilograms per day in block No. 2.

The increase in the production capacity of alumina production at the Ural Aluminum Plant as well as the reduction in the amount spent for raw and processed materials and the absolute size of expenditures for different items of sectional and all-plant expenditures, in connection with simplifying the structure of production management (consolidating alumina sections into one and consolidating sectors in this section) and improvement in repairs led to a reduction in production costs. A marked reduction in production cost also took place at other alumina enterprises in the aluminum industry.

The cost of one ton of alumina at the Volkhov plant decreased 28% between 1955 and 1956. At the Bogoslovskoye plant the cost of one ton of alumina was greatly reduced and at present this plant produces the cheapest alumina in the country.

4. Cost Price of Aluminum

A comparison of the cost price of raw aluminum and an analysis of the dynamics of the different expenditures makes it possible to determine the most favorable conditions for production and potentials for lowering production cost.

In 1950-1956 all technical factors improved at aluminum plants which contributed to reducing the production cost of aluminum. This was achieved through intensification of production by increasing current in the electrolytic series, the use of acid electrolytes with a minimum number of anode effects, and a reduction in the production cost of alumina.

For instance, the prime cost of one ton of aluminum in 1950 was 2.4 times greater than in 1956 at the Kanaker Aluminum Plant, 2.2 times greater at the Kandalaksha plant, approximately twice as great at the Dneprovsk and Volkhov plants, 1.75 times greater at the Stalin plant and 1.4 times greater at the Ural plant.

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At the Volkhov plant during the first years of its reconstruction the production cost of aluminum was reduced. However, in the next years of the fourth five-year plan, in connection with the gradual shift to its own alumina obtained from nephelines where production was not yet mastered and the cost of this alumina still exceeded the cost of imported alumina, there was a sharp increase in the cost of aluminum.

At all plants there was a higher cost level during the assimilation period which cannot be considered a normal phenomenon.

The higher production cost level is the consequence not only of difficulties in adopting new capacities but in organizational shortcomings in putting aluminum plants into operation.

The conditions attendant on mastering the postwar capacities of the restored electrolytic section at the Dneprovsk plant were complicated by poor hearth blocks which had been used in assembling the cells. This circumstance was the cause of the high aluminum production cost at this plant in 1949.

Expenditures on alumina as represented in the cost price of aluminum at the separate plants are given in Figs. 10, 11, 12 and 13 for 1940-1956.

The lowest level of expenditures for alumina during this period existed at the Ural Aluminum Plant which is the consequence of lower consumption and the lower cost of alumina production at this plant. At the Bogoslovskoye Aluminum Plant there was a constant drop in expenditures for this item based on a systematic reduction in alumina consumption and production cost. The lack of a local raw material supply for alumina production at the Stalin plant causes the high cost of alumina in the production cost of aluminum.

At the Dneprovsk plant the great expenditures for alumina were also caused by an incomplete period of mastering the newly introduced capacities during the period 1949-1950.

At the Ural plant the expenditures for alumina represented approximately 36-31% of the production cost of aluminum.

Expenditures for this item rose 21.7% from 1941 to 1950, largely because of higher prices.

In 1956 expenditures for this item decreased due to the reduction in the proportion and production cost of alumina, being 36.4% less than in 1950.

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At the Stalin plant in 1950 there was a marked increase in expenditures for alumina over 1943 (general increase 32.3%, made up of 38.5% for higher prices and reduction in consumption of 6.2%) while from 1950 to 1956 expenditures decreased 47%.

The reduction in the consumption of alumina at plants was achieved by improved operation of cells, reduction in losses from pulverization and alumina transportation, carrying out measures for improving the condition of floors in shops which made it possible to utilize alumina sweepings, alteration in the design of bunkers and the welding of rims to the cells to prevent spillage of alumina (Stalin Aluminum Plant), replacement of worn louver and the power supply.

The increased consumption of alumina was caused by insufficient hardening in the alumina furnaces. Considerable losses in alumina took place in transportation for long distances because of poor-grade containers.

Discontinuity in the consumption of alumina at different plants and the achievements of the Ural Aluminum Plant testify to the presence of considerable potential for a further reduction in expenditures under the item "alumina" in the production cost of aluminum.

At the Volkhov plant the consumption of alumina was lower than for 1940 and 1950.

At the aluminum plants the potentials for reducing expenditures for the item "alumina" are connected with improving the power supply, hardening and crystalline structure of the alumina, further extension of up-to-date methods in economizing on raw and processed materials in all corps and brigades of the electrolytic sections, improvement in working conditions and increased skill of workers, improvement in means of transportation within the factory and in hauling for long distances.

Expenditures for fluorine salts make up approximately 4-6% of the cost price of raw aluminum.

During the period under consideration (1940-1956) expenditures for fluorine salts became a smaller item in the production cost of aluminum.

Starting with 1949 factories started using calcium fluoride which is much less expensive than cryolite and aluminum fluoride.

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Additions of calcium fluoride contributed to reducing the consumption of cryolite. Calcium fluoride reduced the melting point of the electrolyte and contributed to the stability of the production process.

The reduction in expenditures on cryolite at the Ural plant was due not only to the reduction in consumption but to the increase in the proportion of flotation cryolite in total consumption of cryolite from 7.4% in 1941 to 52% in 1950 and 1956 (Table 25). The proportion of flotation cryolite in the total consumption of cryolite increased during the fifth five-year plan at other plants also and stood at 57.4% in 1955 and 63.4% in 1956 at the Stalin plant, at 57.7% in 1955 and 52.5% in 1956 at the Dneprovsk plant, and at 40% in 1956 at the Volkhov plant. The reduction in the consumption of aluminum fluoride in 1955 and 1956 can be explained as lesser utilization in acid electrolytes.

TABLE 25

PROPORTION OF FLOTATION CRYOLITE IN TOTAL CRYOLITE CONSUMPTION AT THE URAL PLANT, IN %:

Consumption of flotation	1941	1942	1943	1944	1945	1946	1947	1948
cryolite as a proportion of total cryolite consumption	7.4	5.8	34.8	32.9	32.0	34.4	43.2	43.5

cryolite as a proportion	1949	1950	1956
of total cryolite consumption	46.7	52.0	52.0

The increase in the consumption of aluminum fluoride during certain years was caused by fluctuations in the power supply at aluminum plants, wearing of cells and the increase in the alkalinity of the alumina. In 1956 the lowest consumption of cryolite per ton of aluminum was obtained at the Kandalaksha (18.5 kilograms) and the Kanaker (28 kilograms) plants. At other plants where cryolite consumption per ton of aluminum was higher there were great potentials for reducing expenditures for cryolite.

The greatly increased consumption of flotation cryolite in 1956 at the Ural and Stalin Aluminum Plants can be explained as the entry into operation of electrolytic cells of the various corps following their redesigning. Figures from the Volkhov plant on the consumption

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of aluminum fluoride during the prewar years were lower than during the postwar years which confirms the possibility of a further lowering of expenditures for fluorine salts.

Possibilities for reducing expenditures for fluorine salts must follow the line of reducing the production cost of the cryolite used which requires the organization at all plants of special installations for cryolite flotation and the recovery of fluoride exhaust gases as well as by reducing the consumption of fluorine salts.

Expenditures for anode materials make up 9-11% of the cost price of aluminum. At all plants during the period 1940-1956 there were great fluctuations in these expenditures, caused by changes in consumption standards and prices.

In 1949 wholesale prices for anode materials and anodes were increased. The increase in prices was the main cause of the increase in expenditures for this item represented in the cost price of aluminum. There was a reduction in expenditures from the point of view of consumption. A certain increase in the consumption of anode materials during various years was due to increased ash, reduced porosity and a tendency to crumble.

At the Ural plant after 1949 there was a marked reduction in the consumption of anode materials related to the new system of shallow immersion of anodes in the electrolyte. At the Stalin plant the consumption of anode materials was greatly reduced following the institution of an anode materials section which resulted in a reduction in losses during transportation.

In 1956 the Kanaker and Kandalaksha plants occupied first and second place (485 and 520 kilograms per ton, respectively) in the consumption of anode materials.

At the Volkhov plant this item of expense reflects the specific features of the designs of multianode cells with baked anodes. Expenditures for anodes were 1.5 to 2 times higher than for anode materials.

The consumption of anodes at the Volkhov plant was constantly reduced due to an improvement in quality and greater mastery of the electrolytic process. In 1956 consumption was 28% lower than during the prewar period and reached approximately the consumption level of anode materials at other plants. A further reduction in expenditures for the item "anode materials" was obtained by reducing the production cost and by reducing consumption through assuring a uniform power cycle, improved anode maintenance and better quality of anode materials (reduction in ash content, reduced porosity, increased mechanical strength).

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Expenditures for electric power fluctuate between 15-30% of the production cost of aluminum and depend principally on the cost of the energy employed which can be seen from data provided in Figs. 14, 15, 16 and 17.

Expenditures for electric power represented in the production cost of aluminum reflect directly the efficiency of the geographical location of the aluminum plants, their closeness to the power supply and its quality.

This statement can be confirmed by the level of rates for electricity. The Dneprovsk plant operates on cheap power from the Dneprovsk Hydroelectric Power Station which is in the immediate vicinity.

The Kandalakska, Nadvoitsy and Kanaker Aluminum Plants also operate on cheap hydroelectric power as can be seen from data cited in Fig. 18.

The consumption of electric power also has a real effect on reducing the production cost of aluminum. During the period under consideration the consumption of electricity has declined from year to year. For instance, the consumption of electricity per ton of metal dropped 1149 kilowatt hours at the Ural plant, 4811 kilowatt hours at the Stalin plant, 3418 kilowatt hours at the Volkhov plant and 1663 kilowatt hours at the Dneprovsk plant.

The Volkhov plant made the best showing on the consumption of electricity in 1956 (Fig. 19).

The consumption of electricity per ton of metal depends on many factors, among them the most important are cell design and quality of installation; power cycle; quality of maintenance.

Let us consider each of these factors separately.

Cell design and installation quality. In view of the differences in design of the different cells, the separate series operated on different electric power patterns. Cells with oval shells operated on lower current than rectangular cells due to higher heat transmission since with higher current they became overheated which led to disintegration of the lining and leaking of the electrolyte.

In a corps where different types of cells were installed current was maintained approximately as for oval cells.

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A comparison of power factors of different series over a number of years showed the advantages of rectangular cells without bottoms which assured a higher output per cell per day and a lower consumption of electric power even when operating on lower current.

The Stalin plant had the first installations of oval cells. Defects in the oval design with poor-grade installation led to their being out of operation in a very short time. The electrolytic section of the Stalin plant was redesigned with the replacement of oval cells by rectangular ones which assured a lower consumption of electric power and improved other technical and economic aspects of the operation of the section. Work was done at the enterprises on replacing obsolete cells with worn shells by more modern cells.

Measures were also carried out on reducing resistence in circuits of electrolytic cells: leads were strengthened, anode and cathode contacts welded, bolt contacts of bars and pins were replaced by wedge contacts. In order to lengthen the service of the cells worn channel bar shells were replaced by shells of sturdier design, short shells replaced by longer ones, cells assembled with joint overlap.

Power system. The main power factors determining the operation of electrolytic cells at the Ural Aluminum Plant are cited in Fig. 20. During 1942 and 1943 at the Ural plant the current fluctuated greatly which led to a reduction in output per current and to an increased consumption of electric power. In 1944 the current was comparatively stable, voltage was reduced and the consumption of electricity declined. In 1945 and 1946 there were considerable fluctuations in the electric power supply to factories, however, thanks to raising the level of the metal in the cells, it was possible to increase output on the basis of current and energy and reduce the consumption of electric power.

After 1948 the current was stronger which resulted in an increased output on the basis of current and energy. Raising the level of the metal in the cells contributed to increased output on the basis of current even with lower current. The introduction of up-to-date method of work contributed to reducing voltage in the cell. The reduction of losses in electric power was furthered by the introduction in 1950 of a simpler and more rapid method for quenching anode effects with wooden rods instead of ladles as had been used. Thus, beginning with 1946, power factors improved from year to year and there was a corresponding reduction in electric power consumption.

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The redesigning of cells in the first and second corps which took place in 1946-1948 made it possible to raising output per unit of electric power in these corps from 78 to 81% and higher. The replacement of worn out shells with new ones in other corps, the replacement of covers of "priiamki" [ ], the addition of calcium fluoride to the electrolyte, contributing to a reduction in current losses through the side lining, all this led to increased output per unit of current and reduced the consumption of electric power.

The reduction in the voltage in the cell and the consumption of electric power were also encouraged by measures carried out in 1950 on cleaning contacts of cell leads and the initial welding of cathode contacts and the reduction of the depth of anode immersion by 100 millimeters (in corps No.1).

At the Stalin plant after 1948, following the replacement of oval shells by rectangular ones, current increased greatly and all power factors were improved (Fig. 21).

Improvement in the power supply after 1949 assured improvement in all operational factors at the Stalin Aluminum Plant: increased current, increased output per current unit and reduction of voltage in the cell. Improvement in technical factors in 1950 was achieved as the result of mastering operation with thick side and bottom deposits.

At the Dneprovsk plant the power cycle in 1950 did not reach the level of 1940-1941 as regards output and was lower at the Ural plant (Fig. 22).

The reduction in the consumption of electric power at the Volkhov plant was accompanied by an increase in current which exceeded that planned and by increased output (Fig. 23). The increase in output per unit of current was determined by: raising the level of the metal in the cells even with some increase in the distance between poles; improvement in the power supply; increased skill of operating personnel.

Power factors at the Volkhov plant during the postwar period greatly exceeded the prewar factors and the indexes of the Dneprovsk plant, also operating with cells with baked anodes.

During the fifth five-year plan there was further improvement in aluminum production processes, continued growth in the productivity of electrolysers with a simultaneous reduction in the consumption of electric power per unit of production. A basic trend

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in electrolysis was providing for the operation of cells on more acid electrolytes and with a reduced number of anode effects and increased current density.

The cryolite portion of electrolytes at aluminum enterprises dropped to 2.2-2.4 by the end of 1955 as against 2.8-3.0 in 1951. At the Ural plant the cryolite percentage was reduced from 2.52 in 1955 to 2.45 in 1956, from 2.46 to 2.36 at the Stalin plant, from 2.39 to 2.38 at Kandalaksha and to 2.2 in 1956 at the Volkhov plant.

Thanks to raising the level of metal in the cells and improvement in the power supply the number of anode effects in the cell during a 24-hour period was reduced at the Ural plant from 1.31 in 1955 to 1.05 in 1956 and correspondingly from 1.2 to 0.77 at the Stalin plant, from 1.07 to 0.85 at Kandalaksha and to 0.99 in 1956 at Volkhov.

The greatest success in this field was achieved in 1956 by personnel of the Kanaker plant. The frequency of anode effects at this enterprise in 1956 reached approximately 0.19 per day and 0.12 by the end of the year. The great reduction in the number of anode effects made it possible for the plant to increase the current and the production of the electrolyzers without increasing the consumption of electric power.

During the period under consideration current density in the electrolyzers of all aluminum enterprises increased constantly, by 20% at the Dneprovsk plant, by 16% at the Ural plant, and 16% at the Kanaker plant. In the second electrolytic series at the Ural plant anode current density increased from 0.695 amperes/sq.cm. in 1946 to 0.863 amperes/sq.cm. in 1956, i.e. 24.2%. At the Kanaker plant current density had reached 0.914 amperes/sq.cm. by the end of 1956.

The Volkhov plant, operating on multianode cells, has high output per unit of current: 92.34% in 1955 and 91.21% in 1956, which was assured by operation on acid electrolytes at high current density (1.15 amperes/sq.cm.), maintaining optimal voltage, constancy of current in the series and careful servicing of the electrolytic cells. Power factors by plants in 1956 as compared with the Ural plant are given in Fig. 24.

The quality of servicing of electrolyzers plays a great role in reaching high metal output and in reducing the consumption of electricity. The quality of cell operation improved continuously

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with improvement in techniques of aluminum electrolysis and increased skill of personnel.

During postwar years the skill of the workers improved constantly. Increasing the skill of maintenance personnel and the mechanization of hard jobs (treating cells with pneumatic hammers, mechanization of anode regulation) contributed to improvement in cell servicing and, consequently, to reducing the consumption of electric power.

The reduction in electricity consumption was furthered by the campaign among leading workers for savings of electric power. Assigning permanent groups of cells to work crews contributed to reducing the average voltage in the cell and to reducing electricity consumption.

Further mechanization in managing the anodes and treating the cells, improvement in working conditions, the popularization of up-to-date practices within the plants and between plants will make it possible to assure a higher quality of operation and, consequently, a reduction in the consumption of electricity and processed materials.

Expenditures for wages of production workers made up 6-9% of the production cost of aluminum.

The amount of expenditures in this item depends first of all on labor productivity, the average wage level, the skill of workers, and the organization of work.

Expenditures for wages during the postwar period were considerably higher than those of the prewar period which was related to the increase in the average wage in the aluminum industry and the introduction of a wage system for key jobs in electrolysis which stimulated the output of aluminum and improved its quality by giving large supplements to the basic pay rate. Starting with 1948 the average wage increased markedly as the result of payments for length of service and bonuses for higher-grade metal.

For instance at the Ural plant the average yearly wage of workers in the electrolytic divisions increased 2.8 times from 1941 to 1950. Characteristic of the Ural plant is the continuous increase in expenditures on wages. While this item of expense was 3.6% of the cost price of aluminum in 1941, it had reached 7.6% in 1950 and 8.2 in 1956. In recent years expenditures for wages at the Volkhov plant have started to drop in connection with the rapid increase in labor productivity as compared with the increase in the average wage.

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At the Stalin plant expenditures for wages increased through 1948 which was caused by the rapid rise in pay and unsatisfactory labor productivity under difficult factory conditions of working with wornout oval cells.

The redesigning of the electrolytic section on the basis of rectangular cells contributed to the rapid increase in labor productivity, following which there was a drop in the percentage of the aluminum production cost represented by wages.

The lowest level of expenditures for wages in the itemized production cost of aluminum was reached in 1956 at the Stalin plant which can be explained by the high labor productivity achieved through the operation of powerful cells and the up-to-date work methods adopted by the overwhelming majority of the factory's workers.

The higher level of wages at the Ural plant is the result of higher pay rates and the bonus incentive system.

The level of expenditures for wages is determined by the growth in labor productivity. This factor in turn depends on the design and capacity of the cells, the improvement in the technical aspects of production, efficient labor organization and the electric power supply system. Where there are marked fluctuations in the ampere load over a 24-hour period and an insufficient supply of electric power labor productivity is reduced.

Workers in the main occupations under a system of uneven electric power supply were paid on the basis of corrected output standards as related to current. Such a situation led to an increase in the percentage of production cost spent on wages for the wages per ton of metal increases with lower current. Consequently, one of the most important factors in reducing expenditures for wages was the guarantee of a regular electric power supply.

Another important potential for reducing expenditures on wages is a readjustment of the pay scale and current system of payments, the elimination of indirect piecework and the creation of bonus scales aimed at making them return a profit both from the point of view of nonoverdisbursement of the wage fund and from the point of view of increasing production cost.

Potentials for reducing expenditures for the item "wages of production workers" are also related to improvement in labor organization.

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Extensive dissemination of practices of leading workers within the electrolytic plants and between the various enterprises is a powerful factor in increasing labor productivity and, consequently, in reducing expenditures for wages.

Expenditures on management and maintenance make up 13-20% of the production cost of aluminum.

The size of such expenditures depends to a great degree on the size of the establishment.

Changes in divisional expenditures as represented in the production cost of one ton of aluminum are given in Fig. 25. At the Ural plant we find an increase in expenditures on management and maintenance up through 1946 and a constant decrease in subsequent years. The increase in these expenditures was accompanied by an increase in metal output and was the consequence of adding new production capacity, attended by large additional expenditures. The sharp increase in divisional expenditures in 1943 reflected increased reserves for amortizing expenditures for electrolytic cells. A further reduction in divisional expenditures was caused by a rapid increase in metal production.

At the Stalin and Volkhov plants there was a constant reduction in sectional and all-plant expenditures in the production cost of aluminum, thanks to an increase in the output of metal.

At the Dneprovsk plant the level of sectional and all-plant expenditures was raised in 1950 as the result of putting new series of electrolytic cells into operation as well as the imperfect utilization of available capacities during the course of the year.

The lowest level of divisional expenditures was at the Ural plant in connection with larger scale production and better production organization than existed at other enterprises.

During the period under consideration estimates of sectional expenditures increased as the result of higher wages for auxiliary workers and engineering and technical personnel and increased expenditures for routine repairs.

Potentials for reducing sectional and all-plant expenditures are related to increasing production output, primarily through a better utilization of available equipment both from the point of view of capacity and time in operation, and to an absolute reduction in their total dimensions at enterprises. Reducing the total

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sum of sectional expenditures is connected with reducing amortization expenditures for electrolytic cells.

The increase in the average length of service of cells makes it possible to reduce amortization figures and consequently reduce the production cost of metal.

Reducing the percentage of aluminum production cost represented by sectional expenditures should follow the line of reducing the cost of repair operations carried out in basic and repair divisions. The high cost of operations in the machine repair shops can be explained by shortcomings in the organization of production: high percentage of defective work, many hard jobs are not mechanized, a whole series of production standards are established by the practical-statistical method and not by a technologically based system, and not all factories make studies of the length of service of parts and units subject to rapid wear.

The size of sectional and all-plant expenditures per unit of production may be reduced considerably by increasing the utilization of the capacity and operating time of equipment, i.e. increasing the smelting of metal.

A most important indication of the utilization of the capacity of electrolytic cells is the output of metal per cell-day.

An indication of output per cell per day is the synthetic indication of the operation of the electrolytic sections which reflect the power pattern, the conditions of the cells and the level of maintenance. During the war and the first postwar years the power supply fluctuated greatly, there were breaks in the power supply, worn out equipment was kept in operation, and repairs were not of a high caliber. All this caused a reduction in the output of aluminum per cell per day. After 1948 there was an improvement in all qualitative indications of the operation of electrolytic sections thanks to improved and intensified production processes, the replacement of worn equipment by improved types, improvement in the power supply and in cell maintenance.

A systematic study and general adoption of up-to-date work methods by the entire body of workers in electrolytic sections must assure a further increase in output per cell per day.

The period between major repairs can be lengthened by the more extensive use of the unit repair system.

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Reducing the idle time of cells for repairs and increasing their length of service will increase the production capacity of the electrolytic sections.

The reduction in all-factory expenditures may be attained first by eliminating nonproductive expenditures.

At the Dneprovsk plant in 1950 nonproduction expenditures made up 36% of the total sum of all-plant expenditures, at the Stalin and Ural plants 25%, and at Volkhov 17.4%. Nonproduction expenditures are to a large degree connected with railroad demurrage charges. In 1950 demurrages at the Ural plant averaged 11.7 hours as against a standard 6.5 hours.

The elimination of nonproductive expenditures in paying fines comes through better financial discipline and improved operation of transportation divisions in the area of better mechanization of loading and unloading operations, providing satisfactory unloading frontages at sectional and all-plant warehouses, and improvement in the organization of loading and unloading operations.

The reduction in production cost has taken place not only by reducing material expenditures(raw and processed materials, electric power) but by reducing expenditures for maintenance and administration through better production organization and a simplification of the structure of enterprises. For instance, at the Ural Aluminum Plant two alumina sections were consolidated into one. Six production sectors were formed from twelve then existing. All this made it possible to simplify management, increase the operating factor and reduce expenditures for administration through the elimination of superfluous echelons.

Expenditures on management and maintenance at the Kandalaksha Aluminum Plant in 1956 were reduced considerably through modifying the organizational structure and the use of a divisionless system of administration.

Through the elimination of superfluous echelons in the administration, expenditures on the maintenance of the administration and managerial apparatus at this plant were reduced by 2,800,000 rubles per year while the number of engineering and technical personnel and white collar workers decreased 130 men.

The reduction in administration and managerial expenditures should aim at further efficiency in the managerial structure and the reduction of excessive staffs.

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Simultaneous with the reduction in expenditures for material and power and improvement in the utilization of the production capacity of electrolytic sections was the improvement in the quality of aluminum smelted.

For instance, the output of high-grade A00 and A0 aluminum was 73% at the Ural plant in 1956, 82% at the Stalin plant, 75% at the Dneprovsk plant, 82% at Volkhov, 71% at Kanaker, etc.

The movement of leading workers and innovators which spread among workers in the basic and auxiliary occupations has played an enormous role in reducing the production cost of aluminum.

A decisive improvement in qualitative indexes, the liquidation of losses from uneconomic and nonproductive expenditures, the introduction of economic accountability within the plant, the increase in labor productivity based on a further adoption of the latest achievements of science and technology, improvement in the forms and methods of production and labor organization and the all-round study and dissemination of the up-to-date practices of innovators are the necessary prerequisites for a further reduction in the production cost of aluminum.

Chapter V

PROSPECTS FOR THE FURTHER DEVELOPMENT OF THE SOVIET ALUMINUM INDUSTRY

1. Main Features in the Geographical Location of Industries with Heavy Energy Consumption

Plans for the future developement of the aluminum industry are determined by the required scale and rate of development of the national economy and its separate branches.

As indicated in Comrade Khrushchev's address delivered at the Twenty-first Congress of the CPSU on target figures for the development of the Soviet national economy during the period 1959-1965, aluminum has in recent years been acquiring greater and greater importance as a metal for diversified use in industry and construction.

The seven-year plan aims at a 2.8-3 fold increase in aluminum production.

Any substantial increase in aluminum output must be based on the construction of new plants.

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The location of enterprises in the aluminum industry is determined by a number of factors characteristic of all industries requiring large energy consumption. Among them are predominantly branches of heavy industry which play an important role in strengthening the industrial and commercial potential of the country, specifically the aluminum, zinc, synthetic rubber, magnesium, and liquid fuel industries, etc. Their expansion can be assured by an enormous increase in the production of electric power.

The current seven-year plan is a decisive step in carrying out Lenin's concept of the over-all electrification of the country.

In 1965 the production of electric power will increase to 500-520 billion kilowatt hours, i.e. from 2-2.2 times greater than in 1958; the established capacity of electric power stations will more than double.

In this connection considerable importance is attached to the problem of the effective location of the power-consuming industries.

The location of the different branches of industry is influenced by the nature of the technical processes involved.

The nature of the technical processes involved in the different energy-consuming industries is not identical.

However, it is possible to isolate features common to all these industries: a high consumption of different types of power per unit of production; the great portion of the cost of power equipment in the total cost of the fixed assets; the large percentage of power expenditures in the production cost; the high level of power requirements per worker.

The relatively great expenditures for power among the production expenses of industries using a great deal of electric power renders most important the presence of major sources of cheap power in deciding on geographical location. The transmission of power over long distances leads to increased production cost and excessive transmission loads which reduces the possibility for expanded production in the national economy.

Where there is great consumption of power the quality of the power supply acquires enormous importance since even with a slight difference in the cost per unit of power (1 ton of ideal fuel, the first kilowatt hour, 1 ton of natural fuel) the production cost changes markedly.

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The small consumption of labor in the power-consuming industries per unit of power capacity has exceptionally great importance in their location in new areas.

We must start out not only from the characteristics of the specific power source but take into consideration its place in the total power balance of this or that area of the country, in close connection with the economic specialization of the area. Predisposing factors for the location of power-consuming industries must be considered against the power potentials of the area as a whole, in relation to their structure, and with consideration for the time needed for assimilating available power supplies and technical and economic factors of the individual power sources and the entire power system of the area (individual capital investiments in the construction of new power supplies, the production cost of power, the degree of regulation, the cost of obtaining fuel and power transmission). The power supply of an economic region is determined by the balance method against the prospective development of the basic branches of industry which define the specialization of the area and of other power consumers within a given area.

In locating a power-consuming industry we must start with a consideration of the industrial and economic complex of this or that area.

The location of industries requiring considerable supplies of power, subordinated to the principle of the nearest possible location to power sources, must start from party directives on the preferential construction of new enterprises in the eastern areas of the country where the richest power resources are found as well as with the aim of deconcentrating and evenly distributing industry throughout the country yet keeping them close to sources of raw material, fuel and areas of consumption.

In the location of energy-consuming industries their structure and the quality of electric power sources is of particular importance.

The production cost of electric power obtained from heat-power and hydroelectric power stations reveals quite large fluctuations, depending on the following circumstances:

natural conditions (size, shape and depth of coal seams and the quality of coal, nature and quality of water and power resources - regulation of rivers, pressure, etc.).

technology of power resource utilization (production systems, mechanization and automatic control of processes, the adoption of improved technical methods for utilizing power resources);

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the size of the electric power stations;
the level of organisation of production at central electric power stations;
the possibility of using secondary sources of power-waste from coal preparation).

The location of power-consuming industries within the limits of a selected power system with positive economic features cannot be carried out arbitrarily. Under these circumstances we cannot omit consideration of the transportation of the basic types of raw material or the possibilities for locating new centers of consumption or centers with a labor supply. We must also take into consideration the technical possibilities and the economic feasibility of electric power transmission.

Where transmission costs are high industries consuming considerable electric power are located near sources of electric power, electric central power stations, since an increase in the cost of electric power increases the cost of production in the industry which uses the power.

A qualitative description of the source of electric power must meet the requirements of the electric power consumer with relation to the pattern of the electric power supply during a 24-hour period, a month and a year.

2. Specific Features in the Location of the Aluminum Industry

The specific nature of the location of the aluminum industry is determined by the characteristics of the raw material being processed, and by the structure and nature of the technical processes.

The aluminum industry includes three main production links: the mining of bauxites or other raw material for aluminum; the production of alumina; the production of aluminum by the electrolysis of cryolite-alumina melts.

Subsidiary links in the production of aluminum are the extraction of raw material containing fluorides and limestone, the production of fluorine salts and the production of electrodes.

In the production of alumina great quantities of heat are consumed in the form of steam for preheating and evaporating by-pass solutions, for cooking the bauxite pulp in autoclaves and for removing silicon from aluminate solutions.

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Electric power is used at alumina plants for power purposes.

Since it requires steam of low and medium potentials, the production of alumina provides an advantageous situation for the combined production of heat and electric power.

The value of the location of the fuel supply as a source of industrial fuel and steam acquires great importance in the location of alumina production since expenditures for power make up a relatively large percentage of the production cost.

At the same time, under all methods of alumina production, the material index for comparison fuel is below the material index for raw material and limestone take together.

The predominance of expenditures for raw material over expenditures for power determines the practicality of locating alumina plants near the source of raw materials. The greatest consumption of material and power is found in the processing of a nepheline concentrate, thus inclining toward location near sources of limestone since 10 tons of the latter is used to produce 1 ton of alumina.

When low-calorie fuel is used in processing nephelines, it may be equally as decisive a factor in locating as the limestone aspect. When locating for alumina production we must take into consideration the districting of fuel consumption in the country and try to combine local fuel resources with the best local raw material resources.

The nearness of alumina production to aluminum plants has a number of technical and economic advantages. However where favorable raw material and fuel factors in the organization of alumina production do not coincide with power factors this condition is not obligatory since approximately 2 tons of alumina is used to produce 1 ton of aluminum while the consumption of raw material and fuel amounts to 8-16 tons per ton of alumina.

Where alumina is being produced from nepheline concentrates the nearness of cement consumers is of particular importance since approximately 9 tons of cement is produced to 1 ton of alumina. The enormous scale of construction operations in all areas of our country may insure the sale of this side product from alumina production; nevertheless in order to have the least transportation expenses it is desirable to be able to dispose of the cement near the production site.

Thus one of the most important conditions for effectively locating alumina production facilities is the question of size and location of the raw material supply, the degree to which it has been

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studied geologically and the level of technology in alumina production which determine the possibility for using well-known minerals containing alumina.

For this reason an appraisal of the alumina raw material supply from the point of economic geology is a necessary prerequisite for planning the efficient location of alumina production in our country.

The production of aluminum is a process requiring high consumption of electricity, making particular demands on the quality of the electric power supply. The percentage of electric power consumed is approximately 18,000 kilowatt hours (alternating current) per ton of metal. The electric power is consumed in the form of direct current for technological purposes and in the form of alternating current for power purposes. The electric power supply system must be constant with regards to current strength and voltage during the normal operation of the electrolytic cells and somewhat heightened in voltage and lower in current force during the period when the cell is being put into operation. The starting and operating cycle of the cells is determined by the specific nature of the design of the cells installed. Breaks in the electric power supply are inadmissable. Frequent interruptions for short periods disrupt the operations of cell series, increase the average voltage in the cell and cause an increase in the consumption of electricity. Long interruptions in the electric power supply lead to a cooling of the smelted solutions and to throwing the cells out of operation.

The aluminum plants include large transformer substations which convert alternating current into direct through mercury rectifiers or motor generators. The percentage of the cost price of aluminum represented by the electric power factor fluctuates widely (15-30%) depending on the cost of the electric power and the size and organization of the enterprise.

A reduction in the cost of electric power by 1 kopeck with other conditions remaining equal reduces the cost of 1 ton of metal by 180 rubles and allows the plant to maintain a capacity for 100,000 tons of aluminum per year for a sum of 18,000,000 rubles.

Where aluminum plants require very great electric power consumption, great national importance is attached to the assurance of cheap power resources. The transmission of electric power over long distances causes unnecessary expenses in the national economy.

Aluminum plants must be located near cheap power bases and may be located at some distance from the production of alumina and other materials.

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Thus the location of aluminum plants must be oriented on inexpensive and extensive power supplies which will assure the production of controlled electric power.

The combination of alumina production with the electrolysis of aluminum is a favorable factor in reducing the cost of the metal (alumina losses in transportation are reduced) but it is not obligatory where extensive sources of cheap power are not available in the area where alumina is produced.

Combination in the aluminum industry has a real meaning since in this case there is a reduction in the production cost, transportation is reduced, there are fewer losses in raw, processed materials, and semifinished products, there is less demand for working capital and the use of fixed assets is improved.

Particularly effective is the combination of alumina production with the electrolytic process which guarantees:

the elimination of expenditures for special containers, the transportation of the alumina and a reduction in capital investments for special rolling stock; reduction in alumina losses from pulverisation during transportation; reduction in the size of warehouses for the alumina;

considerable economy in fuel used in hardening alumina since where it is used immediately there is no necessity for deeper hardening which is required for alumina which has to be hauled for a long distance;

savings in capital investments in subsidiary and auxiliary items (repair, transportation, water supply);

consolidation of the power system and increase in its efficiency.

Where alumina and aluminum production are combined it is practical to include a heat-power station in this complex to provide the necessary amount of steam for alumina production and electric power for the electrolytic process.

The shifting of a heat-power electric power station completely to a heat-power schedule is feasible if there is available another source to provide electricity for the aluminum electrolysis and where there are alumina capacities exceeding the alumina requirements of the electrolytic division in the combine.

Prerequisites for the combined production of alumina and aluminum may be the following factors:

1. The presence of an extensive fuel and power supply with low-calorie fuel. In this case the production of alumina independent

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of its methods of production (with the exception of the processing of nepheline concentrate) must be moved near the fuel supply since low-calcric fuel brings the fuel index up over all other indexes in alumina production.

2. The presence of alumina raw material (bauxites, nephelines, aluminites) in the region of the power supply center for the aluminum plant.

Aluminum production can be efficiently combined with the production of the anode material. This combination assures advantages of a technical nature in carrying out the electrolytic process. The reduction in the viscosity of the anode material following its immediate use has a favorable effect on the electrolytic process. As operations at the Bogoslovskoye and Stalin plants have shown, the import of anode materials was accompanied by pulverisation and contamination of the briquets during transportation and storage which made the electrolytic process more difficult and led to a deterioration in the technical and economical aspects of the operation of the electrolytic plants.

Under specific conditions, in the construction of enterprises of the aluminum industry it is essential to take into consideration the time factor, which can be demanding in individual cases in connection with the necessity for the most rapid development of this branch of industry, and not establish the whole complex in a single spot all at once despite the practicality of combination. Under these circumstances the required combination connections may be temporarily replaced by cooperation with already existing enterprises where the increase in production will require smaller capital expenditures.

Practical sizes of individual complexes in the aluminum industry are determined first, by the interests of the national economy and that of separate regions where the aluminum industry is to be developed. The effectiveness of deconcentrating new construction in a large number of small places or of concentrating it in a small number of large centers is determined by the following principles:

1. Technical and economic advantages of organizing large alumina or aluminum plants are related to possibilities for improved technology and apparatus (the use of larger production units) with more complete mechanization and automatic control of all processes in the basic and auxiliary divisions with less expenditures for administration and the auxiliary services.

2. A decisive factor in the concentration of the aluminum industry (a complex of enterprises or separate production) is the trend in the development of the different areas of our country. The

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intensive development of industry in the eastern part of the country even before the war has determined the necessity for finding large sources of raw materials and power in this region. The priority of selecting this or that source for exploitation is determined not only be the interests of the aluminum industry but by a whole complex of objectives in the expansion of the economy of this or that region (power, metallurgy, machine-building, chemistry, railroad transportation).

The degree of concentration of aluminum production near the supply of the huge hydroelectric power resources of Eastern Siberia will be determined not only by the absolute size of the power supply but by the size of the development of other branches of this industry and of the national economy as a whole.

3. Prospects for the Expansion of Aluminum Production

The importance of raw material resources in the expansion of the aluminum industry is exceptionally great. On the correct and complete solution of the problem of raw material in the aluminum industry depends the self-sufficiency of the country in raw material in a certain area.

As the result of systematic geological prospecting conducted by the government in all districts of the country during the five-year plans, the raw material supply of the aluminum industry has expanded rapidly. The Soviet Union occupies one of the first places in the world with regard to raw materials for aluminum. Compared with 1929 the bauxite reserves in 1933 were 717 times greater, in 1938 13.1 times greater and in 1956 tens of times greater (including marked increases in high-grade bauxite reserves carried on the industrial balance [?]).

As distinct from the slow and sporadic growth in raw material reserves in the capitalist countries the increase in reserves for the Soviet aluminum industry has taken place continuously. We must also mention the more uniform distribution of the reserves territorially, the tendency to a decentralization of reserves as distinct from the increasing inequality of their distribution in the capitalist countries.

The exploitation of separate sources of raw material for the aluminum industry and deposits in the Soviet Union is taking place in a planned fashion on the basis of a united economic plan, in particular the plan for the territorial organization of the economy and a comparative economic evaluation.

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Sources of raw material discovered during prospecting operations are also being brought into use in a planned, efficient and scientific fashion.

The increase in reserves of aluminum raw material will be one of the basic factors determining the specific rate of expansion of the aluminum industry in the long-range plan for the development of the Soviet national economy.

The task of developing the raw material supply must be solved with a view toward assuring the aluminum industry the resources needed for producing the greatest amount of metal in the shortest time and at the lowest cost in the economically preferable areas of the country.

The Soviet Union possesses rich and diverse sources of aluminum raw material which assure the extensive development of the Soviet aluminum industry. Bauxite deposits have been discovered and prospected in the Northern, Central and Southern Urals, in Leningrad and Vologda Provinces, in Central Kazakhstan, in Buriat-Mongolia, in Krasnoyarsk Territory and in the Ukraine.

The development of a large aluminum industry in the USSR and the increase in the scale of alumina production connected with it have required the expansion of the raw material supply for the aluminum industry.

Until recently the basic raw material for the production of alumina was bauxite. This can be explained largely from the fact that the aluminum content of the commercial grades of bauxite is higher and the silicon dioxide content lower than in other aluminum ores. However, in addition to bauxites, industry will be able to use other types of nonbauxite raw material with satisfactory technical and economic results. Many types of nonbauxite raw material has the advantage over bauxite in containing in addition to aluminum oxide other useful elements such as, sodium and potassium in nepheline, alkali and sulfur in aluminite, etc. For this reason the industrial processing of these ores into alumina is quite feasible and quite advantageous, despite the lower content of aluminum oxide, if the processing is done by a compound method, i.e. not only the aluminum oxide but the other valuable components of these ores are also utilized.

One of the types of raw material for producing alumina are the nephelines. The largest nepheline-syenite deposits in the world are

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located in the Kola Peninsula. In addition, deposits . nepheline-containing rocks have been found in other areas of the Soviet Union, in Krasnoyarsk Territory, in the Armenian SSR, in the Ukraine, in Transbaikalia and other places.

A main source of nepheline raw material of commercial importance are at present the nepheline waste from the concentration of apatite-nepheline ore.

Nephelines, as raw material for the production of alumina, are of a lower grade than the bauxites (in aluminum oxide content) and for this reason they can be utilized profitably only by compound processing with the simultaneous extraction of other components.

As the result of years of research in the Soviet Union a method has been developed and adopted in practice for producing aluminum oxide, alkalies and cement from nephelines.

When nephelines are utilized the capital investment for the production of the soda required for alumina is less inasmuch as the nepheline processing utilizes the alkali coming from the nepheline itself.

The principal advantages of the Kola nephelines as a source of alumina are:

1. Nepheline tailings from the apatite concentration factory exclude the necessity of expenditures for mining, grinding and milling;

2. The uniformity of the chemical composition of nepheline tailings assures a constant technological process in the production of alumina which to a great degree facilitates production (over the processing of bauxites);

3. In processing nepheline the only additional raw material needed is limestone while the processing of bauxites requires soda, lime and other processed materials;

4. The presence of alkalies in nepheline makes it possible not only to do without soda in processing but makes it possible to obtain calcined soda and potash as by-products;

5. The production of cement from waste slags in nepheline processing.

At present nepheline concentrate is being successfully processed at the Volkhov Aluminum Plant.

The long-range plan for the expansion of the aluminum industry aims at constructing alumina plants in a number of areas of the country on the basis of the nepheline raw material supply.

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Also included in the complex ores are the alunites; they are found in thick and compact masses along the earth's surface which makes their mining in a large scale by the open-pit method much easier and simpler.

The total amount of useful components in alunite rock reaches 50-55%.

The processing of alunites for alumina does not require expenditures for soda as is necessary in the case of bauxites.

Extensive research has been done in the USSR on the compound processing of alunite rock. As the result of research now being done a method for the compound processing of Zaglik alunite ores into alumina and other products has been selected.

The rapidly growing requirements of all possible branches of the national economy for aluminum and aluminum alloys is leading to the necessity for rapid growth in the production of alumina in our country. The current method of producing aluminum by electrolysis of cryolite-alumina melts is extremely complex, requires the consumption of large amounts of alumina, soda, fluorine salts and electrodes.

Capital outlay for the equipment for alumina plants, transformer substations and electrolytic shops is extremely high.

All this makes it necessary to expand the aluminum industry on the basis of new and simpler production methods and new types of raw material.

The greatest amount of aluminum is used in the form of alloys with other metals.

The basic alloying metal in aluminum alloys for casting purposes is silicon.

Silumin is produced in the Soviet Union by smelting electrolytic aluminum with silicon. In this connection attention should be given to the fact that at alumina plants a large amount of labor, energy and material is expended on silicon removal. At the same time the silicon must be reintroduced into the aluminum to produce silumin.

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This contradiction is partially or wholly eliminated when aluminum-silicon alloys are produced by the electrothermal method. The electrothermal method for producing silumin is particularly useful in utilizing natural ores containing aluminum and silicon, through by-passing the alumina production and aluminum electrolysis stages. The problem of producing silumin by the electrothermal method has been worked on for a number of years in the Soviet Union. However until recently the electrothermal method for silumin production had not been applied in practice.

Achievements in the technology and equipment used in electrothermal methods for producing aluminum alloys as well as progress in the concentration of raw material are making it possible to consider material with a high alumina content as provisional raw material for the production of aluminum.

As already mentioned the Soviet Union has very rich reserves of raw material with a high alumina content. Deposits of raw material with a high alumina content are known in the various parts of our country.

The use of raw material with a high alumina content in the production of aluminum will greatly expand its raw material reserves and make it possible to organize aluminum production in a number of areas with power resources but without local sources of other types of alumina raw material.

The introduction of electrothermal methods for producing aluminum and aluminum alloys will assure an increase in metal output, a transition to metallurgical aggregates of greater capacity with a high coefficient of energy utilization, a simplification of technological cycles, reduced cost of production and achievements in higher labor productivity and savings in capital investments through the elimination of the alumina production stage. The introduction of the electrothermal method in the aluminum industry, i.e. the production of aluminum directly from ores by direct reduction in electric furnaces, assures a reduction in capital expenditures by more than a third and a reduction in operation expenses by almost 20%.

This increase in the production of aluminum in the eastern part of the country on the basis of cheap electric power from large hydroelectric power stations required the creation there of an extensive source of supply of aluminum raw material.

For this reason great importance was attached to prospecting in these areas and to technological tests of other types of raw

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materials for aluminum with the aim of bringing them into industrial utilisation as rapidly as possible as had been foreseen by a number of the government's decrees. In Krasnoyarsk Territory practically inexhaustible riches of nepheline syenites and a number of bauxite deposits have been discovered.

Further study of alumina raw material reserves and continued research on deposits already discovered in the eastern part of the country as well as continued research in the adoption of nonbauxite processing will make it possible to provide raw material for the fast-growing demands of the aluminum industry and bring it closer to power sources thus contributing to the rational geographical distribution of the aluminum industry which is a most important factor in the expansion of the production forces of the Soviet Union.

During the seven-year plan for the expansion of the national economy of the USSR for 1959-1965 the Soviet people are faced with major objectives in expanding production capacities and in increasing the actual output of aluminum and alumina.

Extension of aluminum production during the next years will be based largely on the use of power from the rivers of Eastern Siberia, the fuel reserves of the Kuznetsk Basin and Eastern Siberia, bauxite deposits of the Kazakh S.S.R. and the over-all processing of nephelines from Eastern Siberia and Zaglik alunites. The use of new complex types of aluminum raw material will make it possible to produce soda products, cement, fertilisers, sulfuric acid and others along with alumina.

New enterprises of enormous capacities will be built and put into operation in the eastern part of the country. The great growth in the power capacity and cheap electric power of the eastern areas will create favorable conditions for the expansion of aluminum production.

A large aluminum industry will be developed during the new seven-year plan in Krasnoyarsk Territory on the basis of cheap electric power from the Krasnoyarsk Hydroelectric Power Plant. The cost of alumina will be 40% lower than in leading extant plants in the Soviet Union and the cost of aluminum will be 25-30% lower than the cost of aluminum now being smelted.

As indicated in the report by N.S. Khrushchev at the Twenty-first Congress of the CPSU on target figures for the development of the national economy during the period 1959-1965, the relative role of the eastern areas will increase to 71% of the total aluminum production by 1965.

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Aluminum plants plan to install electrolyzers of high capacities with overhead current lead-in and with mechanization and automatic control of the electric cycle of cell operation.

As the result of new, more uniform and efficient placement of enterprises in the aluminum industry transportation expenses will be greatly reduced.

The reduction in the production cost of aluminum will also be furthered by increased compound utilization of raw material, production waste, and better extraction of rare elements found in aluminum raw material. The cost of aluminum will drop by approximately 20-22%. The increase in the role of the eastern areas in the total metal output will be an important factor in reducing the cost of aluminum since the cost in the factories of Eastern Siberia will be considerably cheaper than in other areas due to the low cost of electric power.

Along with the construction of new plants there will be an important increase and improvement in the utilization of the capacities of enterprises already in operation. Existing plants must turn out more than 25% more alumina.

The creation of a large aluminum industry in the USSR will contribute to progress in technology in many branches of the national economy, to intensified expansion of branches producing the means of production, will strengthen the economic and defense might of the country and will accelerate the move towards communism.

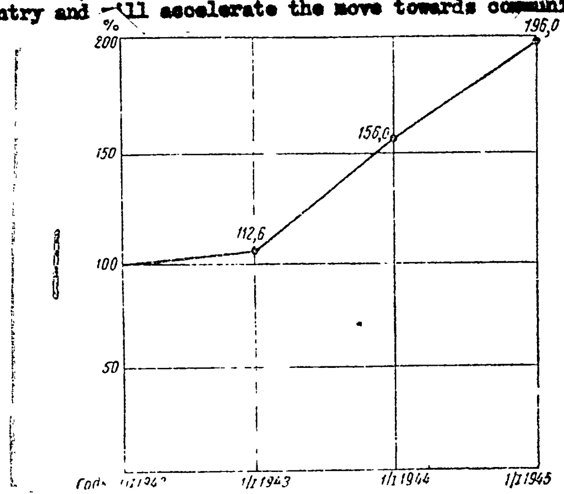

Fig. 1 Changes in the production capacity of bauxite mines during the period, 1941-1945, in %.

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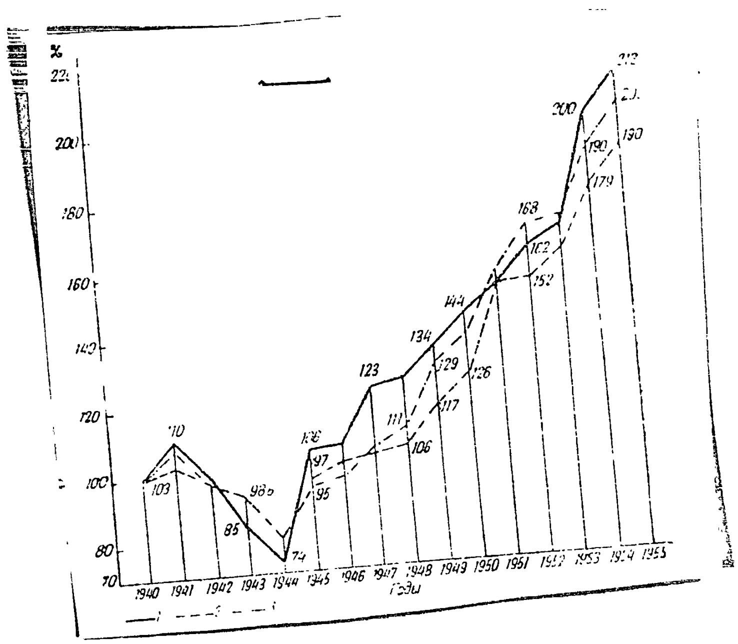

Fig. 2 Changes in labor productivity in cubic meters of rock in underground operations, 1940-1945.
1. Per stope worker 2. Per underground worker 3. Per surface worker

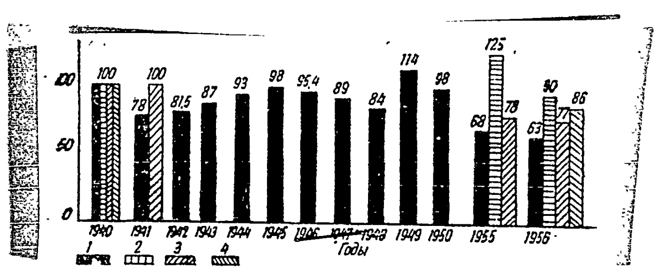

Fig. 3 Production cost of one ton of alumina at aluminum plants during 1940-1950 in %.
1. Ural plant 2. Volkhov plant 3. Tikhvin plant 4. Dneprovsk plant.

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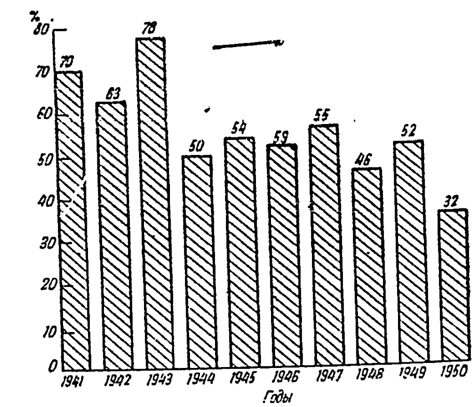

Fig. 4 Production cost of 1 ton of bauxite during the period 1941-1950 by open-pit methods in % of underground methods.

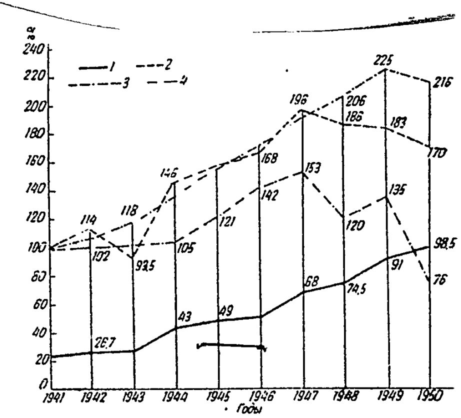

Fig. 5 Changes in the cost of one ton of bauxite during the period 1941-1950, in %;
1. underground extraction 2. cost by underground method
3. open-pit method 4. average

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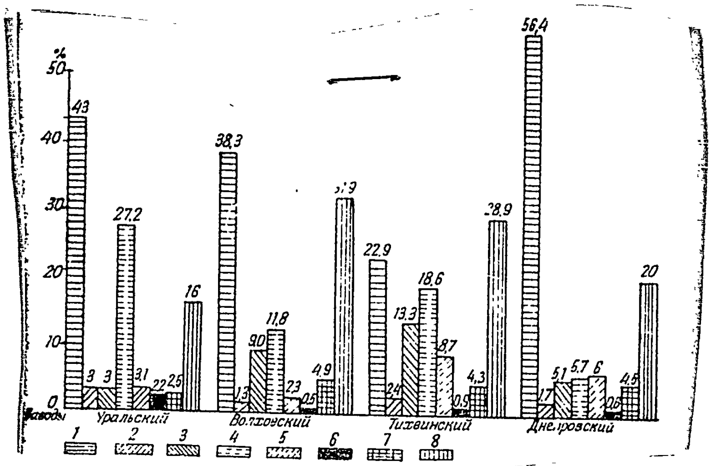

Fig. 6 Structure of the Production Cost of One Ton of Alumina at Different Plants in the period 1940-1941, %.
1. raw material and principal processed materials less waste products; 2. auxiliary materials; 3. fuel; 4. steam power; 5. electric power; 6. water; 7. wages of production workers; 8. division and all-plant expenditures.

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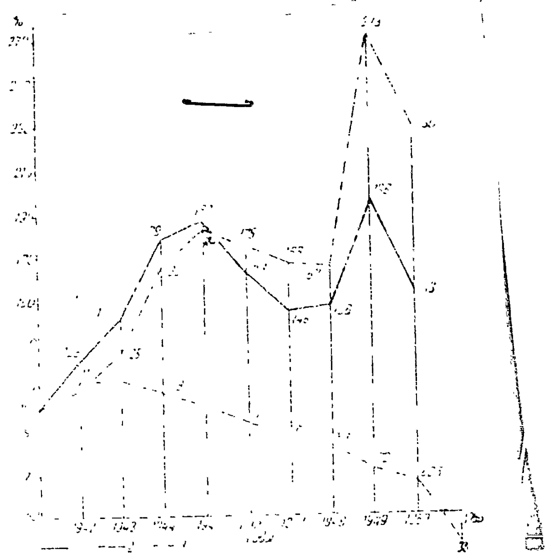

Fig. 7 Changes in expenditures in caustic soda represented in the cost price of alumina at the Ural plant during the period 1941-1956, %: 1. expenditures for caustic soda in the cost price of 1 ton of alumina; 2. consumption of caustic soda per ton of alumina; cost price of 1 ton of caustic soda.

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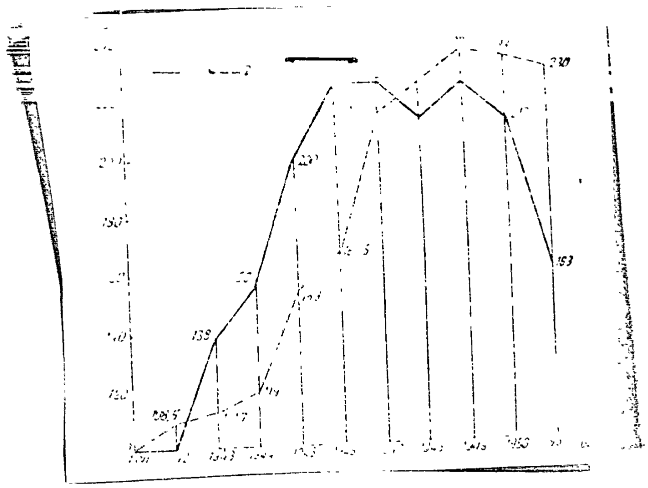

Fig. 8 Changes in expenditures for wages in the cost price of one ton of alumina at the Ural plant during the period 1941-1956, %;
1. portion of alumina cost price devoted to wages
2. ave[illegible]rly wage of workers

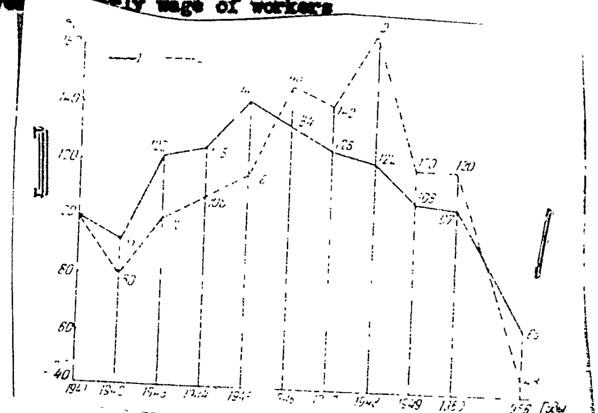

Fig. 9 Changes in expenditures for managing and maintenance in producing one ton of alumina at the Ural plant in 1941-1956, %:
1. section expenditures in producing one ton of alumina
2. all-plant expenditures in producing one ton of alumina

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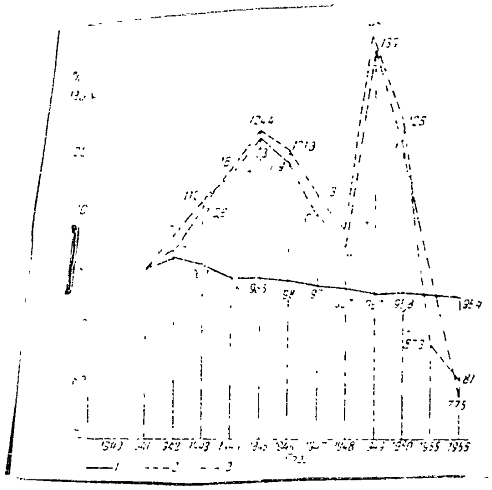

Fig. 10 Changes in expenditures for alumina as represented in the production cost of 1 ton of aluminum at the Ural plant during the period 1940-1956, %; 1. consumption of alumina per ton of aluminum; 2. cost of 1 ton of alumina 3. expenditures for alumina represented in the production cost of 1 ton of aluminum.

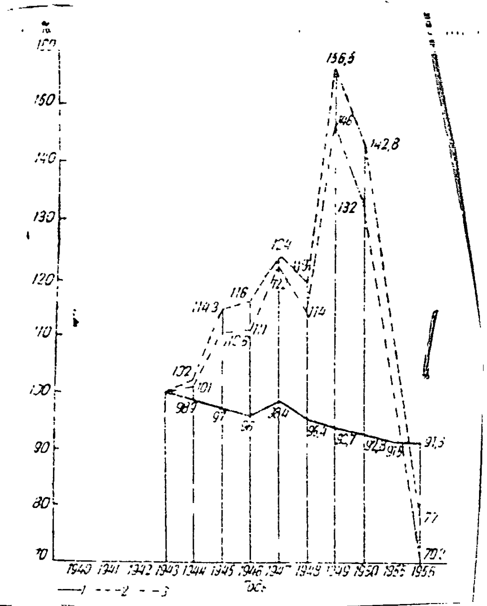

Fig. 11. Changes in expenditures for alumina represented in the production cost of 1 ton of aluminum at the Stalin plant during the period 1940-1956, %: 1. consumption of alumina per ton of aluminum; 2. cost of 1 ton of alumina, 3. expenditures for alumina represented in the production cost of 1 ton of aluminum.

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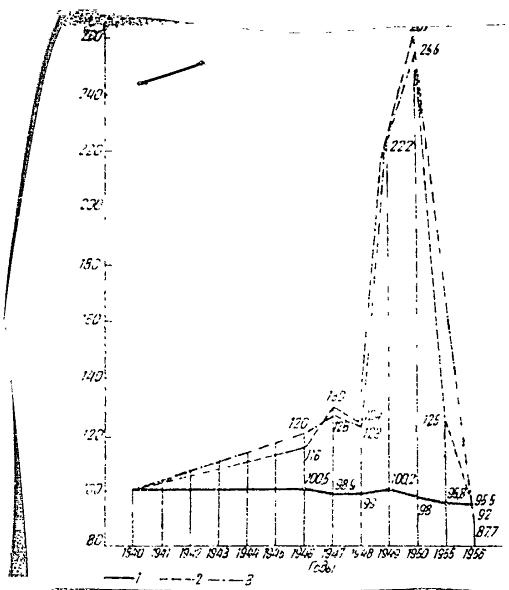

Fig. 12 Changes in the expenditures for alumina represented in the production cost of 1 ton of aluminum at the Volkhov plant during the period 1949-1956, %: 1. consumption of alumina per ton of aluminum; 2. cost of 1 ton of alumina; 3. expenditures for alumina represented in the production cost of 1 ton of aluminum.

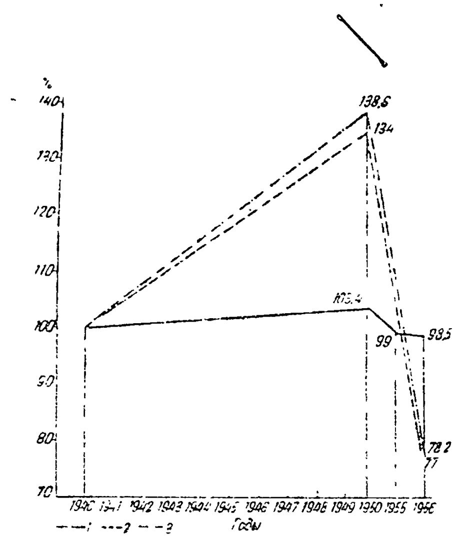

Fig. 13 Changes in expenditures for alumina represented in the production cost of 1 ton of aluminum at the Dneprovsk plant during the period 1940-1956, %: 1. consumption of alumina per ton of aluminum; 2. cost of 1 ton of alumina; 3. expenditures for alumina represented in the production cost of 1 ton of aluminum.

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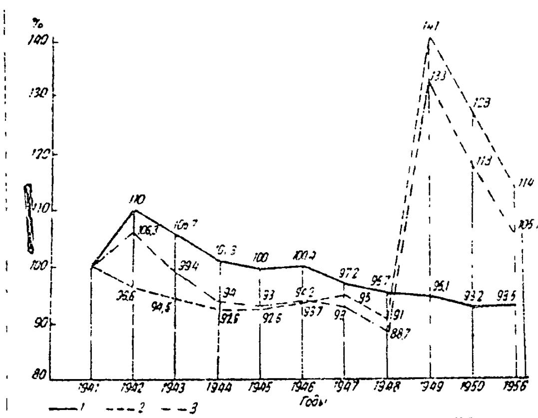

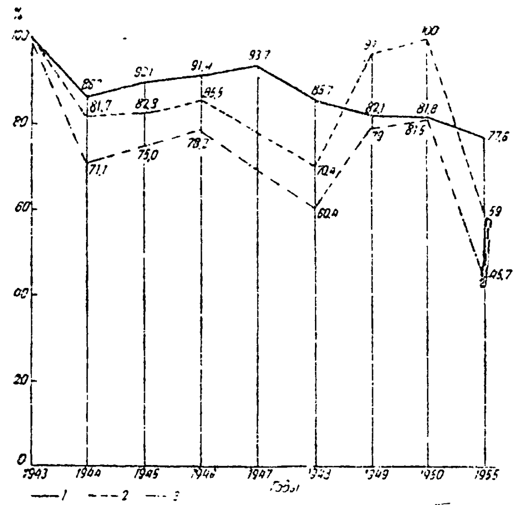

Fig. 14 Changes in expenditures for electric power as represented in the production cost of one ton of aluminum at the Ural plant during the period 1941-1956, in %: 1. consumption of electric power per ton of aluminum; 2. cost of 1 kilowatt/hour of electric power; 3. expenditures per ton of aluminum.

Fig. 15 Changes in expenditures for electric power as represented in the production cost of 1 ton of aluminum at the Stalin plant during the period 1943-1956, in %: 1. consumption of electric power per ton of aluminum; 2. cost of 1 kilowatt/hour of electricity; 3. expenditures per ton of aluminum.

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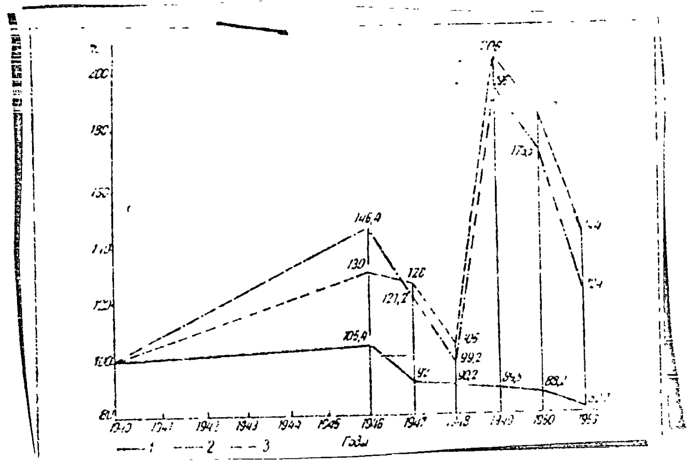

Fig. 16 Changes in expenditures for electric power as represented in the production cost of 1 ton of aluminum at the Volkhov plant during the period 1940-1956, in %: 1. consumption of electric power per ton of aluminum; 2. cost of 1 kilowatt/hour of electricity; 3. expenditures per ton of aluminum.

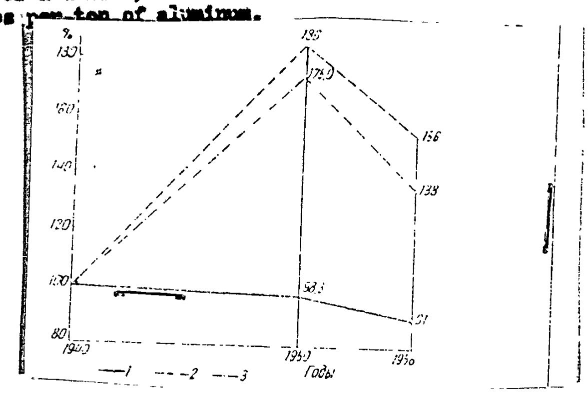

Fig. 17 Changes in expenditures for electric power as represented in the production cost of 1 ton of aluminum at the Dneprovsk plant in 1940, 1950, 1956, in %: 1. consumption of electric power per ton of aluminum; 2. cost of 1 kilowatt/hour of electricity; 3. expenditures per ton of aluminum.

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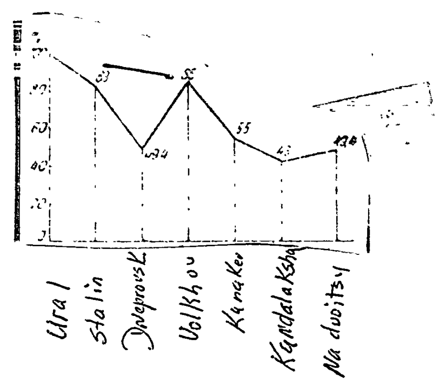

Fig. 18 Price of 1 kilowatt/hour of electricity at different plants in 1956 by comparison with the Ural plant.

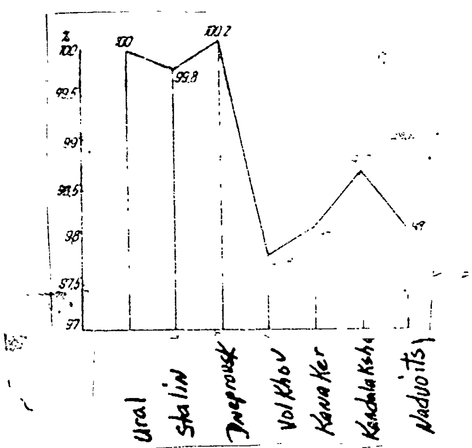

Fig. 19 Consumption of electric power per ton of metal at different plants in 1956 by comparison with the Ural Aluminum Plant.

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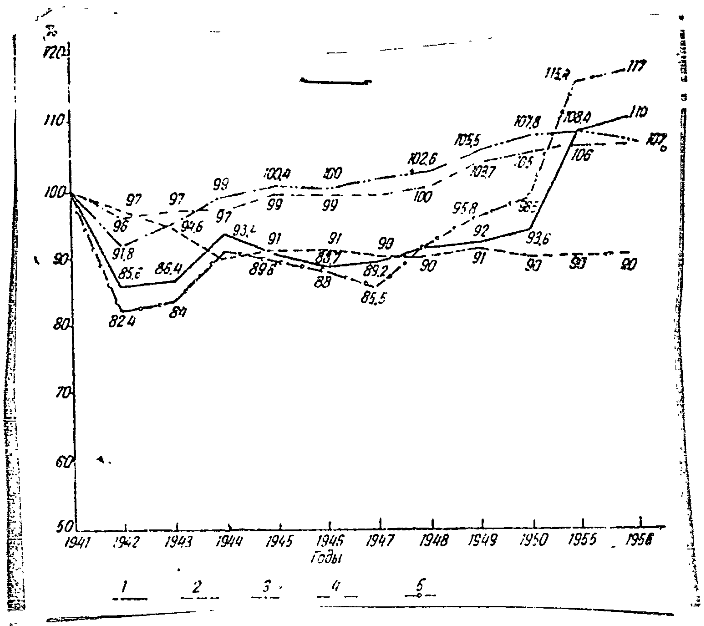

Fig. 20 Principal power factors in the operation of electrolytic cells at the Ural plant during the period 1941-1956, in %:
1. current 2. average voltage in cell 3. output per current unit
4. output per energy unit. 5. output per cell per day

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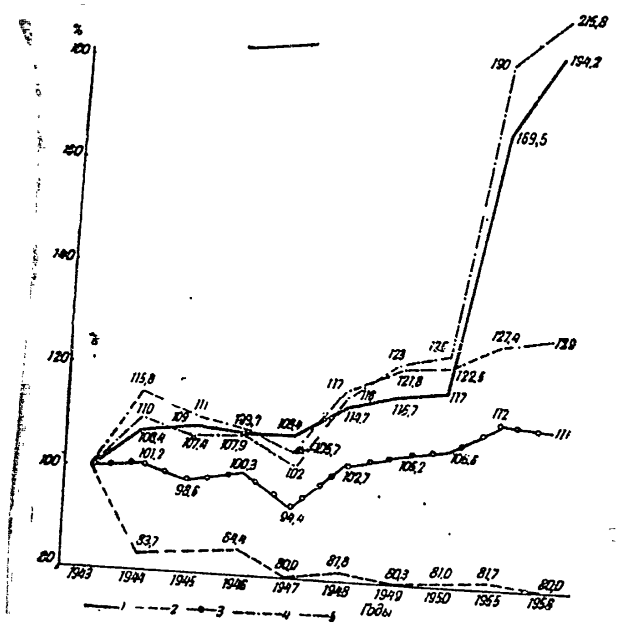

Fig. 21 Principal power factors in the operation of electrolytic cells at the Stalin plant during the period 1943-1956, in %:
1. current 2. average voltage in cell 3. output per current unit
4. output per unit of energy 5. output per cell per day

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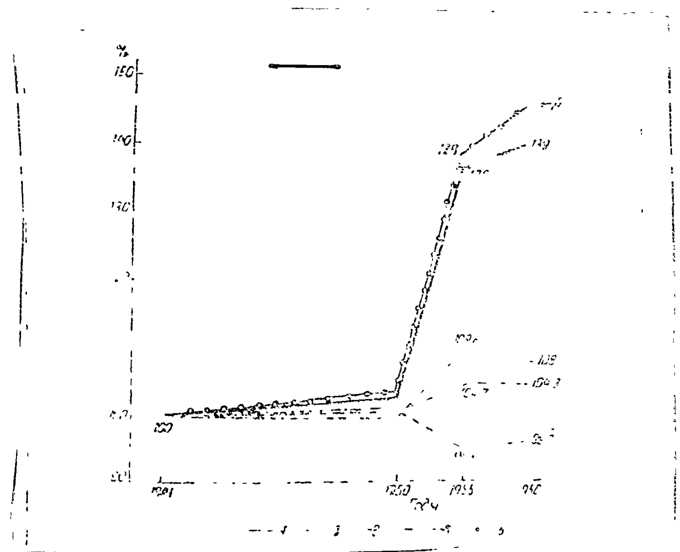

Fig. 22 Principal power factors in the operation of electrolytic cells at the Dneprovsk plant during the period 1941-1956, in %:
1. current 2. average voltage in cell 3. output per current unit
4. output per unit of energy 5. output per cell per day

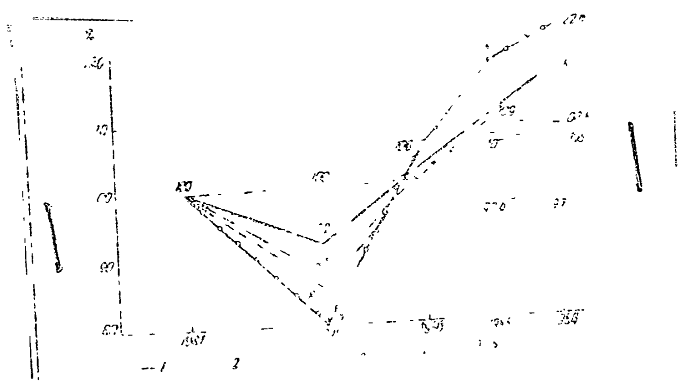

Fig. 23 Principal power factors in the operation of electrolytic cells at the Volkhov plant during the period 1941-1956, in %:
1. current 2. average voltage in cell 3. output per current unit;
4. output per unit of energy 5. output per cell per day

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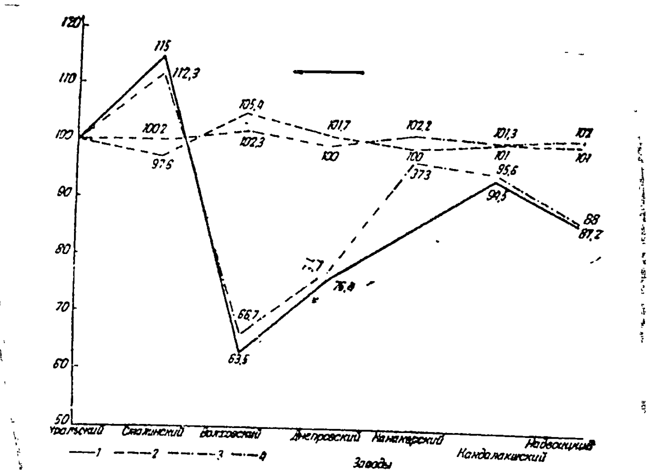

Ural Stalin Volkhov Dneprovsk Kanaker Kanaker Kandalaksha Nadvoitsy

Fig. 24 Power factors for different plants in 1956 by comparison with the Ural Aluminum Plant, in %:
1. current 2. output per current unit 3. output per unit of energy 4. output per cell per day

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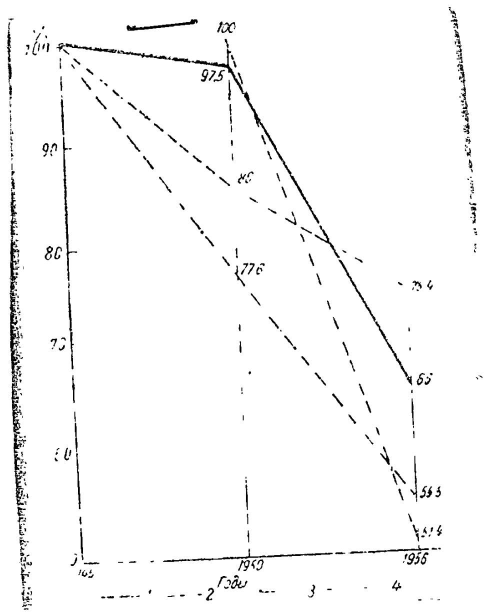

Fig. 25 Changes in sectional expenditures as percentages of the production cost of 1 ton of aluminum.
1. Ural plant 2. Stalin plant 3. Volkhov plant 4. Dneprovsk plant.

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THE END

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