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UNITED NATIONS INDUSTRIAL
DEVELOPMENT ORGANIZATION

Unido/ITD/4
12 January 1968

MINISTRY OF THE ELECTRICAL INDUSTRY OF THE USSR

THE IMPORTANCE OF THE ELECTRICAL INDUSTRY IN THE NATIONAL ECONOMY AND ITS MUTUAL LINKS WITH OTHER BRANCHES OF PRODUCTION

id.68-082

I. THE ELECTRICAL INDUSTRY: THE MAIN TECHNICAL BASIS FOR THE ELECTRIFICATION OF A COUNTRY

One of the most important problems faced by developing countries when determining development priorities is that of the correct and objective evaluation of the role and place of the electrical industry[1/] and its links with the other branches of production.

If this question is viewed in the light of the example of the Soviet Union, a particularly vivid picture is gained of the evolution of the economic potential of the USSR and the transformation of Russia from a backward agricultural country into a mighty Socialist State.

The scale on which electric power is used is an index of the level of development of the productive capacity of any present-day State.

The Soviet Union is scarcely fifty years old. In the life of a State this is but a brief span, but in this short time Russia has witnessed unparalleled developments in economy, science and culture, made possible primarily through achievements in the field of electrification.

Half a century ago, Russia was called 'Darkling Russia'. Today, however, it is flooded with electric light. The country is covered with a dense network of power stations, producing over 550 billion[2/] kWh of electric power per year. This power network extends to the farthest corners of Siberia, the far North and far eastern USSR, and it feeds mighty steel melting furnaces and electrolytic plants and drives trains, rolling mills, excavators, and machines. Today it is hard to name any field of industry, agriculture, transport, building, scientific research or daily life where use is not made of that great force of nature - electricity.

Thus we see the tremendous importance of the electrical industry, the steady and reliable development of which governs the scale of production of

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1/ Both here and later on in this study the term "electrical industry" means, in accordance with the accepted USSR classification, that branch of industry which produces all types of electrical machinery and equipment, transformers, electrical transport equipment, generators, cables and associated fittings, lighting equipment and other heavy-current electrical equipment.

2/ Throughout this document the term "billion" is used to denote one thousand million.

electric power and the ways in which it is transmitted, distributed and used to the best advantage. In other words, the development of the electrical industry determines the economics of power engineering and the electrification of industry.

As the electrical industry is the manufacturing, scientific and technical basis for the electrification of a country and its whole industry, it is one of the key branches of the national economy and is a significant determining factor in the rate of development of the "three pillars" of technical progress: power engineering, technology and the production of new materials.

In order to produce electric power it is necessary to have generators, which are developed and produced by the electrical industry. The same applies to transformers and many other electric power converters, to switching equipment and complete high and low tension installations, to cables and wires - in a word, to everything which is needed for the transmission, distribution and supply of electric power to consumers.

The electrical industry also designs and produces electric power consuming equipment such as electric drives of various functions and sizes, electric motors, electric furnaces, electric welding equipment and other electric units used in industry, and light sources. The generation, conversion, transmission, distribution and use of electric power are controlled by electrical apparatus which is to an ever-increasing degree automatic in operation.

Complex modern assemblies of electrical equipment make it possible to use electricity directly in production processes and help to create radically new technological operations, systems and materials. Modern automated electric operation affords infinite possibilities for increasing the degree of mechanisation and automation, creating continuous production processes and a more efficient and better equipped working force.

The history of the establishment and development of the Soviet electrical industry is rich in examples of the successful struggle for high rates of production, national, technical and economic independence, the mastering of new techniques, and the satisfaction of growing needs in all branches of the national economy for electrical equipment.

Until the First World War (1914-1917) Russia lagged thirty to forty years behind the leading countries of that time in the establishment of an electrical industry, and the Civil War (1917-1921) which followed the World War had the effect of practically wiping out even the feeble industry, which then existed.

The Soviet electrical industry inherited only a handful of industrial undertakings from pre-revolutionary Russia. The production of these factories was of a general nature, without the slightest attempt at specialisation, and they manufactured all types of electrical goods and equipment and dozens of different items used in general machinery construction.

Out of this industry in ruins grew a plan for the development of the country on the basis of electrification, known to the whole world under the title of the GOELRO (State Commission on the Electrification of Russia) Plan. It was emphasised therein that "the operation of electric power stations will only be reliable if there is a parallel development of the electrical industry".

By 1924-1925 the output of electrical equipment and goods surpassed that of 1913. That level of production was not high enough, however, to satisfy the requirements of the programme for the electrification of the national economy. The electrical industry was still not able to produce a number of complicated machines and items of equipment, which had to be imported from abroad. The structure of the industry was out of date, it lacked the most important types of electrical equipment, and a considerable proportion of its equipment was still a legacy from the old days. Moreover, the total amount of investment for the extension of the electrical industry at that time was quite insignificant.

During this period, extensive use was made, in the development of the Soviet electrical industry, of the technical experience of the leading foreign countries, particularly England, Germany, the United States and Austria.

At that stage, the problem of the technical and economic independence of the Soviet State was a most pressing one, and it clearly brought out the need to establish a whole range of new industries.

By making full use of the advantages of a planned economy, this difficult problem was solved. By 1932, the total output of electrical equipment and goods was nineteen times greater than in the pre-war period, and in only five years (1928-1932) the production of electrical equipment increased more than seven times.

It is interesting to note that while before 1930 the growing electrical industry produced mainly goods for general consumption, in the following two years the structure of the industry was radically changed and emphasis began to be shifted to the production of electrical equipment for main-line electric and diesel locomotives, the construction of powerful generators, and the design and construction of other types of electrical equipment.

The primary basis for increased production in every field is heavy industry, which began to be developed at a rapid pace in the thirties, and the electrical industry thus had to master the production of new types of electrical equipment. The metal industry, the machinery industry, the chemical industry and other branches of national industry all called for ever-increasing numbers of electric motors (particularly in large sizes), powerful generators and transformers, electrical equipment, and electrical traction and lifting equipment. The electrical undertakings would not have been able to satisfy the demands of the leading branches of industry for such equipment if the training of cadres of fully qualified engineers and technicians had not been given top priority at this time. By 1932, the number of specialists trained for the electrical industry had more than doubled, while the number of trained factory managers had increased more than three times.

The period from 1932 to 1940 was one of further growth in the electrical industry and increased specialization in its component undertakings.

By the beginning of the Second World War, the Soviet electrical industry was a fully independent branch capable of satisfying the increasing demands of the national economy for the main types of electrical equipment.

There have also been substantial changes in the internal structure of the electrical industry. Taking the overall production of the various factories of the electrical industry as 100 per cent, yearly output may be broken down as follows (see Table 1):

TABLE I

Type of factory	1940	[illegible]	[illegible]	[illegible]
Electrical plant and equipment	38.6	[illegible]	56.7	58.6
Electric cables	46.[illegible]	32.4	[illegible]	[illegible]
Electrical insulators and ceramic products for the electrical industry	1.8	4.9	5.3	4.3
Other products	12.8	12.5	9.3	[illegible]

The Soviet electrical industry has thus made giant strides since the days of the GOELRO Plan. There has been an incalculable increase in production, a great increase in production facilities, and a whole system of specialized scientific research institutes for the electrical industry has been set up. The electrical industry of the USSR has now taken second place in the world in volume of production, and is considerably ahead of the industries of the Federal Republic of Germany, the United Kingdom and France.

The radical changes in the geographical distribution of the electrical industry between 1940 and 1960 may be seen from the figures given in Table II.

TABLE II

Proportion of the total production of electrical goods and equipment accounted for by individual regions of the Soviet Union (per cent)

Region	1940	1961
West and North-West	31.7	15.6
Centre	49.4	37.0
Volga area	3.4	3.5
Urals	2.3	5.8
Western Siberia	-	6.8
Eastern Siberia and Far Eastern USSR	0.2	2.4
Central Asia and Kazakhstan	-	4.3
North Caucasus and Transcaucasia	-	8.9
South (Ukraine)	13.0	14.7
Total:	100%	100%

Radical changes have also taken place in the geographical distribution of the scientific research facilities of the electrical industry. Electrotechnological institutes have been set up in the Zaporozhye, the Chuvash Republic, the Urals, Siberia, Moldavia and in Azerbaidzhan, while new electrotechnological scientific centres are in the process of establishment in Novocherkassk, Donetsk, Tiflis, Frunze, Saransk and other towns.

An idea of the present level of concentration of the electrical industry may be gained by grouping together the various undertakings according to the number of workers employed by them.

Undertakings employing:	Percentage of Total:
up to 200 workers	2.1
from 201 to 500	7.4
from 501 to 1000	13.2
from 1001 to 2000	23.8
from 2001 to 3000	19.9
from 3001 to 5000	16.0
over 5000	17.6

In the USSR, 25 per cent (in terms of value) of all the electrical equipment produced in the country is used in power engineering, 20 per cent is used directly in technological processes, and 55 per cent is used in the manufacture of various electric drive systems.

The following figures, which show the tremendous achievements of the Soviet electrical industry in the production of generators, together with figures for the total installed capacity of electric power stations and the amount of electricity produced, are extremely significant:

	1913	1965
Production of generators, in thousands of kilowatts	11.5	16,800
Installed capacity of electric generating stations, in thousands of kilowatts	1,140	115,000
Production of electric power, in billions of kilowatt hours	2.04	507

Between 1950 and 1965 the production of all types of generators increased more than ten times, that of turbo-generators increased almost seventeen times and that of hydro-electric generators 10.7 times. During the same period, average unitary power of turbo-generators increased [illegible].1 times, while that of hydro-generators increased 1[illegible].7 times.

The output on an industrial scale of turbo-generators with a capacity of 100,000 kilowatts was begun in 1938. In 195[illegible] began the production of turbo-generators with a capacity of 150,000 kilowatts, in 1958 that of generators with a capacity of 200,000 kilowatts, and in 1961 that of generators with a capacity of 300,000 kilowatts. Now in the process of manufacture and assembly are turbo-generators with a capacity of 500,000 kilowatts in single-rotor form and 800,000 kilowatts in twin-rotor form, while development work is being carried out on single-rotor turbo-generators with a capacity of 800,000 kilowatts and turbo-generators with a capacity of 1.0 to 1.5 million kilowatts.

Between 1958 and 1965, 120 turbo-generators with individual capacities of 150,000, 200,000 and 300,000 kilowatts, all produced in factories of the Soviet electrical industry, were installed in thermal power stations of the Soviet Union. In 1965, as many as 60 per cent of the turbo-generators brought into operation in power stations of the USSR had capacities of 150,000, 200,000 and 300,000 kilowatts 1/.

Between 1966 and 1970, 64 to 66 million kilowatts of new capacity will be brought into operation. Most of this new capacity will be attained through the construction of large thermal condenser power stations with a capacity of 2.4 million kilowatts or more, equipped with primarily power-producing units each with an individual capacity of 300,000 kilowatts 2/. Increasing the capacity of thermal power stations, primarily through the use of larger power units, greatly reduces the cost and time of construction and affords considerable

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1/ Elektricheskie Stantsii, ("Electric power stations"), Nos. 3 and 12, 1965; Nos. 1 and 4, 1966.

2/ "Directives of the XXIII Conference of the Communist Party of the Soviet Union on the Five-Year Plan for the development of the national economy of the USSR in the years 1966-1970", section III, para. 10.

savings both in fuel consumption and in the amount of power used for the needs of the station itself.

For the last three decades, the Soviet electrical industry has held the record for the construction of the biggest hydro-electric generators in the world. In 195 , hydro-electric generators with a capacity of 105,000 kilowatts were installed in the "V.I. Lenin" hydro-electric station on the Volga, in 1960 the first hydro-electric generators with a capacity of 225,000 kilowatts were installed in the Bratsk hydro-electric station, and in 1964 a hydro-electric generator with a capacity of 500,000 kilowatts was supplied for the hydro-electric station under construction at Krasnoyarsk.

With these uncommonly powerful electrical machines it has been possible - in record time - to harness the great hydro-electric resources of the European part of the USSR, and to set about harnessing the inexhaustible hydro-electric resources of Siberia.

The progress made in transformer production in the last few years is evidenced by the production of single-unit portable three-phase step-up transformers operating at a maximum of 330,000 volts with a capacity of 400 MVA. The following are now in the process of development and construction: a three-phase 15/220 kV step-up transformer with a capacity of 630 MVA, a three-phase 20/165 kV transformer with a capacity of 400 MVA, a unit of three grouped single-phase 750/545/38.5 kV auto-transformers with a capacity of 3 x 417 MVA, and many others1/.

The latest achievements of the Soviet high voltage equipment industry can be seen in the recently constructed air circuit breakers operating at a voltage of 750 kV and having a cut-off capacity of up to 50,000 MVA, current and voltage transformers and cut-outs of 750 kV capacity, air circuit breakers operating at 220 kV, 2,000A, 1,500 MVA for use in ambient temperatures down to -55° C, highly advanced generator air circuit breakers operating at 15 kV, 14,000A, 3,500 MVA, and others. For the high voltage transmission of direct current, single-anode mercury valves with a maximum capacity of 900A and 130 kV have been developed, while work is now proceeding on a mercury inverter with a capacity of up to 40 MVA.

The highly advanced transformers, valves, inverters, high-voltage equipment, cables and electrical insulating materials supplied by the electrical industry

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1/ Elektrotekhnika, ("Electrotechnology"), No. 2, 1964; No. 7, 1965. Elektricheskie Stantsii, ("Electric power stations"), No. 4, 1966.

have enabled [illegible] for the European part of the [illegible] a unified electric power [illegible] on the transm[illegible] of Siberia to the European part [illegible] a unified high-voltage [illegible] system [illegible] the Soviet Union.

The unified high-voltage [illegible] systems are [illegible] combined [illegible] with an intermediate voltage [illegible] kV [illegible] voltages of 750 kV [illegible] long power-transmission lines [illegible] the Bratsk - Krasnoyarsk [illegible] the Volgograd - Moscow, the Kuybyshev [illegible] operation at voltage of [illegible] kV. Altogether [illegible] approx[illegible] kilometres of 500 kV power lines. An experimental [illegible] operating at 750 kV is being set up between [illegible] direct-current power-transmission line between Volgograd and the Donbass, which has already been completed and brought into operation, is the [illegible] of its kind in the world[1].

The establishment of a unified high-voltage electric power system, first of all for the European part of the country and subsequently for the whole of the Soviet Union, affords considerable and indisputable technical and economic advantages:

- it increases the reliability of the electric power supply to consumers;
- it makes it possible to transmit large amounts of electric power from areas where such power is cheap to produce to areas of heavy demand e.g., from Siberia to the European part of the USSR;
- it reduces the installed generating capacity which would otherwise be needed in power stations, as power can be transferred from one area to another;

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[1] Elektricheskie Stantsii ("Electric power stations", No. [illegible], [illegible]

... parallel ... extremely distant hydro-electric ... power ...

... reserves for ... units, which can ... minimum ...

... brought together into large high-capacity ... parallel working of both the ... ensured under normal ... industry of the USSR has solved this ... powerful synchronous compensators of up to ... the ... transmission lines, special ... electronic ... operating conditions and to their ...

... the western part of the USSR are already linked by ... with the socialist countries of Europe, and in the fore- ... high-voltage power system will cover the territory ... of the latter countries.

... industry of the USSR develops and supplies electric locomo- ... equipment for diesel locomotives, transformers, converters, and ... equipment for traction sub-stations. Extensive electrification of the railways ... carried out in the last ten years, and electric and diesel ... now have an overwhelming proportion of the freight transported on the country's railways. In 1965, this freight amounted to almost two trillion ton-kilometres, or about 46 per cent of the freight handled by the railways of the whole world[1].

Railway electrification amounts to a technical revolution in this important branch of the national economy. There is a complete change to a technically much more advanced fleet of locomotives, together with increases in the running speed and freight capacity of trains, resulting in greater labour productivity and lower rail transport costs.

Electric generating and converting units, electric drives, and other ...

1/ Pravda, 7 August 1966.

electrically-operated equipment are to an increasing extent automatically controlled, and for this reason their control gear is more complicated. The electrical industry of the USSR is developing the production of low-voltage control apparatus - including automatic apparatus - such as contactors, relays for various purposes, control gear, automatic regulators, magnetic, electro-mechanical, electronic and other amplifiers, transmitters of various electrical and non-electric values, measuring and signalling equipment, etc. In recent years, the production of transistorized electronic contactless apparatus for automatic control, Thyristor electric drives and control systems, and complex systems based on control by electronic computers has also been begun. Complete factory-assembled control systems in the form of panels, assemblies and large-bloc panel units are being produced on an ever-increasing scale.

It can be seen from the above that the electrification of the national economy of the Soviet Union is being carried out with the help of an advanced and rapidly developing electrical industry. As technical progress in any country is unthinkable without an electrical industy, it would therefore be advantageous for the developing countries to create their own electrical industry, making the best possible use of imports and mutual co-operation. Otherwise the development of their economies will depend entirely on foreign imports, and as the French say: "He who follows another always lags behind".

The nature of production and the way of life differ from country to country, however, and these are the factors that will determine the structure and scale of an electrical industry.

The Soviet Union is a country with a planned economy. Its great and varied natural resources, its extensive territory and its large population enable it to ensure harmonious development in all branches of its national economy.

II. THE DEVELOPMENT OF INDUSTRIAL PRODUCTION, THE GENERATION OF ELECTRIC POWER, AND THE PRODUCTION OF ELECTRICAL EQUIPMENT

The special place occupied by the electrical industry among the various branches of the national economy is due to the fact that it supplies electrical equipment for use by production workers and is therefore one of the most important elements in building up the forces of production. It makes possible the establishment and re-equipment of industry, and this can lead to a considerable increase in the volume of industrial production.

The connexion between the volume of industrial production and the amount of electric power generated in the USSR is shown by the following figures: in the period 1950-1965, the average annual rate of increase of industrial production in the USSR was 10.9 per cent, while the increase in the rate of generation of electric power was 11.8 per cent. For the period 1960-1965 the figures were 11.1 and 14.3 per cent respectively, but in the period 1950-1959 the rate of increase of electric power production outstripped that of industrial production by only 8 per cent, and indeed during that period electric power shortages were experienced in the Soviet Union, particularly in autumn and winter. Analysis of the statistical data for a longer period, taking into account the development of the main electric power-consuming industries - the chemical industry, atomic technology, the non-ferrous metals industry and the production of high quality electric steel - shows that the production of electric power, in a highly-developed comprehensive economy like that of the USSR, must be 15 to 20 per cent ahead of industrial production.

When studying the economics of the electrical industry it is interesting to note the correlation between the production of electric power and the output of electrical equipment.

There is a direct connexion between the amount of electric power consumed and the production of electrical equipment: the more electric power is consumed, the more electrical equipment is required. The coefficient of this relationship differs from country to country, however, and is subject to variation.

A decisive influence on the relationship is exercised by such factors as the production of electric power, the cost of electrical equipment 1/, the structure of electric power consumption and the variations in that structure within each country and, finally, technical progress in the production of the electric equipment itself.

In the first stages of the electrification of technological processes,

1/ We have in mind only that part of the production of electric equipment which is for internal use.

electricity is used mainly in operations which require the expenditure of substantial power or motive force. Progress is then made to the introduction of electrical machinery and equipment for auxiliary operations, checking and control. In this particular field, less electric power is used, but the cost of the electrical equipment remains high.

With the constant increase in the size of individual units of electrical equipment and of the working speed and speed of rotation of machinery, the specific cost of electrical equipment is falling. This reduction in cost is due just as much, however, to technical progress in the production of electrical equipment, such as the use of new magnetic, insulating and semi-conducting materials, the further perfection of cooling systems, reductions in the levels of magnetic and heat losses, the more uniform distribution of dynamic and heat loads, improvements in production technology, and so forth.

Ultimately the mutual action of all these complex and varied factors also affects rates of growth in the production of electric power and electrical equipment. In the USSR, the mean annual increase in the production of electric power between 1958 and 1965 was 11.9 per cent, while the increase in the production of electrical goods and equipment was 15.1 per cent.

III. THE PROPORTIONAL ROLE OF THE ELECTRICAL INDUSTRY IN INDUSTRIAL PRODUCTION AND IN THE NATIONAL ECONOMY

The present-day industrial production is a complex system of independent but connected branches. The higher the level of development of the productive forces, the more varied and complicated is the production system and the greater the attention which must be paid to the harmonious development of the individual branches of industry and the full utilisation of all the advantages of technical progress.

A most vivid picture of the dynamics of industrial production is provided by an analysis of the rate of growth in labour productivity. For many thousands of years, through the Stone, Bronze and Iron ages, the labour productivity grew at the rate of only a microscopic proportion of 1% per year. It was only when man placed power at his service - first steam, then electricity - that the expenditure of labour on the production of material goods began to drop sharply.

We are now living in an era of unexampled rates of increase in the productivity of labour. This is due to technical progress - to electrification, to the use of new types of synthetic materials, and to the mechanisation and automation of production processes through the use of electric power.

The structure of the various branches of the national economy takes shape under the influence of technical progress. In this structural development of the production sector, a most important role is played by the machine-construction and chemical industries, a major part being played, within the machine-construction category, by the electrical, radio and electronic, and instrument manufacturing sectors.

In developed countries with comprehensive economies, the proportion of the national product due to industry averages 55 to 65 per cent. Of this figure, 22 to 34 per cent is accounted for by machine-construction, while 18 to 22 per cent of the total for machine-construction is accounted for by the electrical industry (including the low-current branch of the industry).

Thus, as far as absolute value is concerned, the electrical industry does not account for such a large part of the gross national product. But the real influence of the electrical industry on the development of the national economy must be evaluated not simply in the light of this quantitative criterion, but primarily in terms of the qualitative improvements in the structure of the national product and in expenditure on the production of material goods, brought about by the electrification of production processes, everyday life, scientific research, and the like.

An accurate picture of this aspect of the development of the national economy of any given country may be obtained by studying the structural changes in the development of industrial production. In the case of the USSR, these changes are characterized mainly by an increase in the proportion of total industrial production accounted for by machinery production and, within the machinery production category, by an increase in the proportion accounted for by the electrical industry.

By 1970, the proportion of the total industrial production of the USSR accounted for by machinery production should reach 27 to 28 per cent, 10 to 11 per cent of which is to be attributed to the electrical industry (in 1965, the proportion of total industrial production accounted for by the machinery industry was 25.8 per cent, of which 9.1 per cent was represented by the electrical industry).

The effect of the accelerated development of the machinery and electrical industries is reflected in the rate of increase in labour productivity in all branches of national production. This is an excellent indication of the role and significance of the electrical industry in the national economy

IV. THE STRUCTURE OF EXPENDITURE ON LABOUR AND MATERIALS IN THE ELECTRICAL EQUIPMENT INDUSTRY

The electrical industry is characterized by a relatively high labour intensity. At the same time, in financial terms the output per worker in this branch is 25 to 30 per cent higher than in machinery production as a whole. This is explained by the fact that in the electrical industry wide use is made of alloy steel and non-ferrous metals, the total value of which is more than 65 per cent higher than all the other materials used in the industry.

The nature of the materials used largely determines the structure of expenditure on the production of electrical goods and equipment. The structure of this expenditure for the electrical industries of several countries is shown in Table 3.

TABLE 3

THE STRUCTURE OF EXPENDITURE ON THE PRODUCTION OF ELECTRICAL GOODS AND EQUIPMENT (PER CENT)

Type of Expenditure	USSR	USA	Federal Republic of Germany	United Kingdom
Materials	71.0	59.0	59.7	57.5
Wages and Salaries	19.0	29.0	28.6	27.5
Other Expenditure	10.0	12.0	11.7	15.0

These figures show that there are close correspondences between the expenditures on materials and on wages and salaries in the electrical industries of different countries. It is true that at first sight it might be concluded that in the USSR the figure for wages and salaries is lower and that for cost of materials higher, but such a conclusion would be a hasty one to draw.

First of all, it must be borne in mind that in the USSR the figure for wages and salaries does not take into account the large sums distributed as benefits through public funds, such as expenditure on free medical attention, the payment of grants to students, pension rights, the provision of sanatorium treatment at advantageous rates, the maintenance of housing resources, and so forth. Secondly, as much as 30 per cent of the value of production in the electrical industry of the USSR is accounted for by the cable sector, which produces not only insulated but also non-insulated conductors, whereas in other countries the proportion accounted for by this class of goods amounts to only 19 to 20 per cent. In the cable industry, the proportion accounted for by the cost of materials is the highest of all branches, and this makes it impossible to compare the expenditure on materials.

When account is taken of these particular features, it will be seen that there is no significant difference between the structure of expenditure in the electrical industry of the USSR and that of other countries.

Nor are there any substantial differences in the labour requirements of the different kinds of work, the average values for which are shown in Table 4.

TABLE 4

STRUCTURE OF EXPENDITURE OF LABOUR (PER CENT)

Type of product	Casting	Machining	Cold stamping	Winding and insulating operations	Fitting and assembly work	Welding	Special processes	Other types of work
1	2	3	4	5	6	7	8	9
Electrical equipment	8.6	18.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.8
Cables and wiring	-	-	-	39.6	-	-	60.4	-
Electro-chemical current sources	-	3.0	5.0	-	4.0	-	86	2.0
Electrical insulating materials and insulators	-	3.0	2.4	0.1	0.6	-	86	10.9
Electric lamp production	-	-	3.0	-	-	-	94	3.0
Average for the electrical industry as a whole	6.3	14.1	12.1	17.0	14.6	7.8	22.6	5.5

From an analysis of the labour requirements for the various types of work, the conclusion may be drawn that there is an important place for female labour in the electrical industry, particularly in the production of low-voltage equipment, low-power machinery and lighting equipment.

The average level of skill of the workers in the electrical industry is higher than in many other branches of industry, as is also the level of qualifications of the engineering and technical staff. In expenditure on scientific research work, the electrical industry comes second, after the aviation industry but ahead of the chemical industry.

All these factors must be taken into account when deciding on the geographical location of electrical undertakings.

Experience has shown that the electrical industry can most advantageously be developed in areas possessing the necessary labour resources and the requisite technical and economic conditions. This was exactly the reasoning followed by the Government of the USSR when it set up an electrical industry in, for example, the Transcaucasian Republics, which only a few decades ago were backward technically, economically and culturally.

The Transcaucasian Republics, particularly Azerbaidzhan, possess considerable resources of fuel and power (natural gas and hydro-electric power), as well as many types of raw material needed for the production of the materials used in the electrical industry. The production of rolled steel has been developed in Georgia, and that of rolled copper in Armenia. Through co-operation, the industries of the Transcaucasian Republics have created the necessary facilities for the development of the electrical industry. Finally, the presence of the requisite labour resources, including a sizeable number of specialists, and the development of an extensive system of training and scientific research institutes have created thoroughly favourable conditions for the successful development of this branch of industry. In only a short space of time the various enterprises making up the electrical industry of Azerbaidzhan have mastered the latest progressive techniques for the construction of electric motors, oil circuit-breakers, electric welding and electrothermal equipment, and the production of new economical electric drives for drilling rigs has been undertaken. Specialized factories have been established for the production of castings and special technical equipment for the electrical industry, and centralised storage and auxiliary undertakings operating at optimum levels and following advanced techniques have been set up. On the basis of the highly developed electrical industry, a scientific, technical and production complex has been set up in the Republic for the development and production of a complete range of large-unit electrical equipment for the oil and gas industry of the whole country.

The electrical industry of the Republic has made a great contribution to the development of power engineering, machinery production and chemistry - all branches which govern technical progress. Azerbaidzhan has outstripped the Federal Republic of Germany and the United Kingdom in the amount of electric power produced per head of population, while the volume of its industrial production grew 1.6 times between 1959 and 1965.

V. LABOUR PRODUCTIVITY AND THE EXTENT OF THE USE OF ELECTRICAL EQUIPMENT IN INDUSTRIAL PRODUCTION

An important index of the development of the economy is the amount of electric power produced per head of population. This particular index is rising rapidly in the USSR and special attention has been paid to accelerating its growth in the once backward peripheral Republics. Thus, while the production of electric power per head of population for the USSR as a whole rose 8.1 times and attained 2,020 kilowatt hours between 1940 and 1964, in the Usbek Republic it increased during the same period almost 12 times (to 929 kilowatt hours), and in the Kirghiz Republic 26 times (to 860 kilowatt hours).

In developing countries this index is extremely small. In 1964, of all the developing countries, only the Republic of Cyprus achieved a production of electric power as high as 545 kilowatt hours per head of population. In other developing countries electricity production is much lower and varies from 401 kilowatt hours in Mexico to 10 kilowatt hours or less in Laos, Ethiopia, the Republic of Dahomey, the Republic of the Niger, Bolivia, Ecuador and other countries.

The increasingly extensive use of electric power in industrial production is accompanied by an increase in the coefficient of electrification (i.e. the ratio of the total power of the installed electric motors to the total power of all installed power sources. For the USSR industry as a whole, this coefficient is close to 0.9. It is at its highest in such branches of industry as machine construction (0.98), light industry (0.97), the chemical industry (0.96) and the coal industry (0.95).

At the present stage of economic development the increase in material production is accompanied by a constant increase in the demand for electric power, which runs ahead of the increase in the number of workers employed in production. As a result, present-day economic progress is everywhere conditional upon increasing the amount of electrical equipment used in the production process, that is to say, the amount of electric power used by each worker in one year. This can be seen from the figures given in Table 5.

TABLE 5

RATES OF INCREASE IN THE AMOUNT OF POWER USED BY WORKERS IN INDUSTRIAL PROCESSES, EXTENT OF PROVISION WITH ELECTRICAL EQUIPMENT AND PRODUCTIVITY OF LABOUR IN USSR INDUSTRY[1/] (COMPARED WITH 1940)

	Year					
	1950	1960	1961	1962	1963	1964
Amount of power used by labour force	1.4	2.8	3.0	3.2	3.4	3.6
Extent of provision of electrical equipment for labour force	1.5	3.0	3.1	3.4	3.6	3.9
Productivity of labour	1.5	2.8	3.0	3.2	3.5	3.8
Ratio of increase of extent of provision of electrical equipment to amount of power used by labour force	1.07	1.07	1.03	1.06	1.06	1.08
Ratio of increase of extent of provision of electrical equipment to increase in productivity of labour	1.0	1.07	1.03	1.06	1.03	1.02

There can be no increase in the extent of provision of the labour force with electrical equipment without extensive and radical changes in the technical equipment of industry, profound changes in technology and, in many cases, changes in the nature of production and even in the products produced. The introduction of electric power is conditional upon these changes and, in its turn, makes them necessary. An increase in the electrical equipment of the labour force is therefore an index of technical and economic progress in industry.

Industrial progress based on an increase in the electrical equipment of the labour force is always accompanied by an increase in the real productivity of labour, for these two indices - the extent of provision of the labour force with electrical equipment and the productivity of labour - are interlinked.

Experience of economic development in the USSR, as in other countries, shows that modern industrial development is accompanied by an increase in the

1/ See "Narodnoe Khozyaistro SSSR v 1964 g." (The national economy of the USSR in 1964), pp. 124, 128, 150, 151; "Promyshlennost SSSR" (USSR industry), 1964, pp. 32 and 81, and Pravda, 3 February 1966.

degree of electrical equipment, which outpaces the general increase in the use of power, thus leading to structural changes in general power requirements in favour of electric power. This is one of the inescapable trends of present-day technical progress.

The ratio of the growth of the extent to which the labour force is provided with electrical equipment to the growth of labour productivity in industry is on the whole close to unity. At the same time, however, in those branches of industry where the increase in the degree of electrical equipment of labour is linked with rapid technical progress, the rises in labour productivity during the period of technical development may considerably outstrip the rise in the extent to which the labour force is provided with electrical equipment (see Table 6).

TABLE 6

RATES OF GROWTH IN EXTENT OF PROVISION OF LABOUR FORCE WITH ELECTRICAL [illegible] IN THE VARIOUS [illegible] (AS PERCENTAGES OF THE 1950 [illegible])

Name of branch	1960	Year [illegible]	1964
Coal:			
Electrical equipment	201	261	283
Productivity	144	160	167
Oil:			
Electrical equipment	171	208	232
Productivity	301	404	431
Iron and steel:			
Electrical equipment	201	246	265
Productivity	[illegible]7	215	226
Chemical:			
Electrical equipment	143	156	163
Productivity	232	290	308
Machine construction:			
Electrical equipment	143	156	163
Productivity	281	352	369
Cellulose and paper:			
Electrical equipment	171	206	217
Productivity	209	231	242
Cotton textiles:			
Electrical equipment	173	190	[illegible]
Productivity	182	190	190

1/ See "Narodnoe Khozyaistvo SSSR v 1964 g." (The national economy of the USSR in 1964), pp. 139, 151. In accordance with the data given in this statistical Yearbook, the rates of growth of the extent to which the labour force is provided with electric equipment are given in the form of data on the average use of electrical power by a single industrial worker. The indices for the labour productivity in the coal and oil industries are likewise computed for a single manual worker. For the remaining branches of industry, however, the figures for labour productivity are computed for a single worker but also include non-manual workers.

These technical and economic [illegible] and trends must [illegible] account in economic planning, and in particular [illegible] and the electrical industry, which must be developed [illegible] other branches of industry.

Thus, in order to attain rapid technical progress in all branches of industry and a general improvement in the economy, it is essential to expand electric power production to the utmost and introduce electricity into all branches of the national economy. A constant increase in the level of electrification and the extent of provision of the labour force with [illegible] equipment is an essential condition for increases in the productivity of labour.

Now that we have described the general role and place of the electrical industry as the main technical basis for electrification and for the development of industrial production and have shown the direct relationship between the extent of provision of the labour force with electrical equipment and the productivity of labour, it would be useful to consider the impact of electrification on a number of decisive branches of the production sector - electric drive systems for the manufacturing branches, electric furnace units in the metalworking industry and electric traction in transport.

VI. ELECTRIC DRIVE SYSTEMS, INCREASED OUTPUT AND INCREASED PRODUCTIVITY OF LABOUR IN THE MANUFACTURING BRANCHES OF INDUSTRY

Soviet economists who have studied mechanized industry have come to the conclusion that "present-day technology has reached the stage at which wide use is made of automatic machine systems entailing a transition from three-unit machine systems (operative parts, transmission, motor) to four-unit systems. The fourth unit, which more and more frequently takes the form of a special cybernetic apparatus, makes it possible automatically to check and regulate the operation of individual machines or machine systems. Here again, electricity is a decisive factor which has transformed the internal structure of technology" 1/

1/ A. [illegible], "Some special features of the development of technology", [illegible] ("[illegible]"), No. 1, 1964, page [illegible].

The significance of the automated electric drive system in the development of mechanized production and the raising of the productivity of labour as a whole, outlined in its most important and general terms, is that it combines in one, three of the four units of mechanical equipment (the motor, the transmission, and the automatic mechanism) and requires only about two-thirds as much electric power as older systems.

Let us consider the role of automated electric drive systems in the manufacturing industry, the development of which is of great significance for the whole economy of a country, and particularly the economy of developing countries. In the developed industrialised countries, the manufacturing industry amounts to 70 to 85 per cent of the whole of industrial production.

Manufacturing industry is the core of technical progress, for it covers the machine-construction and electrical industries, as well as the chemical and metallurgical industries; it serves as the technical basis for construction, as it includes such industries as the building materials industry, the cement industry, the glass industry, and the timber and timber conversion branches of industry; it is the basis for raising the cultural and educational levels of a country, since it includes the printing and cellulose and paper branches of industry, and it raises the standard of well-being and the living standard of the people, as it covers light industry and the food industry.

There are definite correlations between the indices of the development of the manufacturing industry and of its electrification, and a knowledge of these makes methodical and planned development possible.

A reliable index of the influence of automated electric drive systems on the development of industry is the increase in the demand for electric power for motive purposes. Table 7 shows details of the increase in this index in the USSR during the period 1913-1964.

TABLE 7

INCREASE IN THE CONSUMPTION OF ELECTRIC POWER IN INDUSTRY FOR MOTIVE PURPOSES

Year	Total output of electric power in the USSR, in billions of kWh	Consumption of electric power for motive purposes in the industry of the USSR, in billions of kWh	Countries whose total output of electric power in 1964 is approximately equal to the amount of electric power used for motive purposes in the industry of the USSR during the year in question
1913	2.04	1.32	Morocco
1928	5.00	2.9	Zambia
1932	13.5	7.5	Chile
1937	36.2	18.8	Mexico
1940	48.3	24.6	Spain
1950	91.2	44.3	India
1955	170.2	81.2	Italy
1960	292.3	137.2	France
1965	507.0	230	United Kingdom

"Narodnoe Khozyaistvo SSSR v 1964 g." (The national economy of the USSR in 1964), Statistical Handbook, "Statistics" Publishing House, Moscow, 1965, pp. 101-103; Ibid., pp. 91 and 151.

The development of the Soviet Union from an under-developed country into an industrialised one can closely be seen by comparing the amounts of electric power used for motive purposes in the industry of the USSR every year with the amounts of power produced in various other countries in 1964. As shown in Table 7, between 1913 and 1964 the amount of electric power used for motive purposes in the industry of the USSR increased 174 times and has overtaken the entire production of electric power in the United Kingdom.

Another significant figure is that for the increase in the extent to which the labour force of the industry of the USSR is provided with electric motive power during the period under review, in comparison with the growth in labour productivity. Table 8 vividly shows that the productivity of labour in Soviet industry increases at approximately the same rate as the extent of provison of the labour force with electric motive power.

TABLE 8

INCREASE IN THE EXTENT OF PROVISION OF THE LABOUR FORCE WITH ELECTRICAL EQUIPMENT, COMPARED WITH THE INCREASE IN LABOUR PRODUCTIVITY IN [illegible] (WITH 1950 TAKEN AS 100 PER CENT)

	1955	1960	1965
Total extent of provision of the labour force with electrical equipment	146	192	266
xtent of provision of the labour force with electric motive power	141	186	257
Productivity of labour	144	197	248

The increase in the use of electric power for motive purposes is thus the most effective means of increasing labour productivity.

The science of electric motive power is well developed in the Soviet Union and stems directly from the materialistic interpretation of the nature of technology as an aid to labour and to human activity, which is developing in given historical circumstances.

In the Soviet Union, the term "automated electric motive system" covers three basically different pieces of equipment: the electric driving motor, the transmission and the automatic (cybernetic) apparatus. The electric motive system transforms electrical power into mechanical power, transmits it from the electric motors to the operative parts of the machinery and, when necessary, regulates the amplitude, nature and direction of this power, while automatically controlling the operation of the driving motors and of the whole production process.

Automated electric motive power is a most important means of technical progress as it is alone in affording, simultaneously, the possibility of electrification, of mechanisation and of automation in production.

Electric motive power systems are being developed both qualitatively and quantitatively.

With the further development of electric motive units and the electric motive units and the electric motors and power converters which form part of them, there is an accompanying rise in the degree of electrical equipment and the productivity of mechanical equipment, a rise in the coefficient of useful work, and greater opportunity for expanding the scale of production processes and machine units. All this constitutes one of the most important lines of technical progress.

The development of transmission mechanisms and the creation on this basis of machinery powered by multiple individual electric motors, integrally linked with the operative parts of the production machine, make it possible to progress from intermittent production processes to semi-continuous and continuous processes, and this too, is a most important aspect of technical progress.

Finally, the further development of automatic apparatus - the third component element of electric motive systems - secures the best and most advantageous operation of all parts of the electric motive system and hence the most productive and economical operation of the entire unit of mechanical and electrical equipment and of the production process as a whole.

Attempts to develop only individual parts of the electric motive systems, without developing the other parts, lead to inadequate utilization of the potential of the unit of equipment. The experience of the Soviet Union shows that only overall development of all the component parts and of the electric motive unit as a whole can create the necessary conditions for rapid technical progress in the construction of mechanised industrial equipment.

Great importance is attached in the USSR to the social aspects of the development of automated electrically-driven equipment. What we have in mind are such factors as the improvement of working conditions, the mechanisation of labour-consuming operations which require considerable expenditure of physical effort by the workers, the automation of production processes which call for a great expenditure of nervous energy, and others. To some extent, therefore, the electrification, mechanization and automation of production processes is not made conditional only upon the cost of the electrical equipment or the profitability of the initial capital investments required. In industrial undertakings in the USSR, considerable sums are spent on the mechanisation and automation of production in order to secure improved working conditions, even where the direct economic advantage is not evident.

An example of automation which not only offers great advantages from a humane point of view but also presents marked economic advantages is the automation of the scale cars in blast furnace plants which has been carried out in many steel works in the USSR. As a result of this automation, there has been not only an increase in the accuracy of the dispensing of mix and a reduction in the specific consumption of coke per ton of pig iron, but also a sharp drop in the incidence of silicosis and tuberculosis among the scale car operators, who no longer need to be constantly in a hot dusty place under the storage bunkers of the blast furnaces.

In the Soviet Union and a number of other countries, great attention has been paid in recent years to the use of electronic computers for control purposes in the automation of production processes. The use of costly computers for controlling machinery units is only economically efficient, however, if the whole production process, all units of the machinery, and all parts of the electrical motive unit are sufficiently highly perfected from the technical point of view. In the vivid words of Academician A.I. Berg, "it is no use attaching an electronic computer to a wheelbarrow". This once again bears out the view that the development of all parts of an electric motive system must be integrated and co-ordinated.

If we study the history of the development of such pieces of machinery as blooming mills, rolling mills, blast furnace equipment, metalworking machines and presses, excavators, papermaking machines and coal-cutting machines, we see in each case that the development and perfectioning of these machines has gone hand in hand with the development of systems of automated electric actuation. In the USSR, electric motive power has become the power basis for industry, transport, and daily life, and in the near future it will become the power basis for agriculture as well.

The total installed power of electric motors in Soviet industry rose from 2,000,000 kW in 1928 and 14.2 million kW in 1940 to 120 million kW in 1963[1].

1/ "Promyshlennost SSSR" (USSR industry), Statistical Year Book, "Statistics" Publishing House, Moscow, 1964

As an example of the exceptionally high level of development of electric motive systems in the USSR we may take blooming mills. The electrical equipment of these pieces of machinery is approximately twice as large as that of the largest capacity blooming mills constructed in other countries. The installed power of the driving motors of the "1300" blooming mill is over 30,000 H.P. The maximum production of Soviet blooming mills is more than twice as high, and the average production more than three times as high as that of mills abroad.

A high level of electrification of the mining industry has been attained in the USSR, particularly in the boring of oil and gas wells. The productivity of drilling rigs driven by electricity is 25 to 30 per cent higher than that of rigs driven by diesel engines.

There is an extremely high level of electrification in opencast mining workings, where single- and multi-bucket excavators with electric motors of an installed power of over 10,000 kilowatts for each excavator are in use. The largest colliery elevator installations have electric driving motors of about 4,000 kilowatts.

With the experience of the electrification of mining machinery gained by the Soviet Union it can be stated that the automatically regulated electric driving systems fitted to most items of mining machinery ensure 10 to 15 per cent higher productivity, greater reliability in the machinery and improved working conditions compared with unregulated electric drives of the same power.

Until recently, the wide use of automatically regulated electric drives in the mining industry was hindered by the relative complexity and high cost of such drives and also by the absence of properly perfected systems for the economic regulation of the speed of alternating current electric motors. Advances in high-power semiconductor technology have enabled these difficulties to be overcome, however. Successful industrial-scale tests of automatically regulated thyristor direct current drives for coal-cutting machines are being carried out in the USSR.

Automatically-regulated direct current electric drives continue to keep their monopoly of driving units for colliery elevators (for electric drives of over 1,500 kilowatts capacity), single-bucket excavators with a bucket capacity of two cubic metres or more, and machinery feeding drilling rigs.

The dynamic characteristics of the loads in mining machinery and the arduous conditions in which such machinery is used make it necessary to envisage the use of electric drives without reduction gear.

Electric motive power has become the power basis for present-day machine tool construction. It can be said without exaggeration that all progressive trends in the development of machine tool construction are, to a greater or lesser degree, contingent upon the perfection of electric motive power for the machines: that is, the development of electrification. Electrification is the starting point for new and progressive technological processes in metalworking which can lead to great savings.

In recent years particular attention has been paid to the development of machine tools which programmed electric control and of automatic lines of machines, the high productivity of which is largely due to their high degree of electrical automation.

The general tendency in the development of machine tool construction is towards increasing the degree of electrical equipment of the machine assemblies and increasing the proportion of their physical makeup and cost represented by the electrical part. The widely different designs of machine tools and the conditions in which they operate mean that they also pose a wide range of requirements to the electric motor and electrical equipment industry. These specific needs of the machine tool industry are satisfied by the large and varied range of electrical equipment available.

On an average, every metalworking machine tool produced in the USSR is equipped with 3 - 4 electric motors and 5 - 7 electro-magnetic units. At the same time, however, the USSR produces heavy machine tools, each equipped with several dozen electric motors (of a total installed power of as much as 1,500 to 2,000 kilowatts), hundreds of other items of electrical equipment, and also many accurate and fast-acting electrical regulators which maintain a given type of operation by the machine tools. The functional work load of the electrical part of many types of machine tools is very heavy. In this connexion, the combination into a single unit of the electrical and mechanical parts of many machine tools is a matter of particular importance.

Over the last few decades, there has been a rise in both the number and power of the electric motors used in machine tools. If we take the average degree of motor equipment of a machine tool produced in the USSR in 1940 as 100 per cent, the average degree of motor equipment of a machine tool produced in 1964 is approximately 200 per cent.

In the main, the electrification of machine tools still takes the form of using electricity as a source of motive power. In this respect, electricity is used only indirectly in the traditional mechanical working of metals by machine tools. This is far from being the most effective way of using it, however. Electricity can be used directly in technological processes, thus considerably increasing their efficiency. This aspect of the electrification of machine tools has not yet been adequately developed, but it is of great importance and holds out great possibilities.

In any country, regardless of the level of development in the economy and the electrical industry, it is of advantage to organise laboratories or research institutes specializing in automated electric drive systems, to study the problems of the electrification, mechanisation and automation of production. The broad scientific and practical outlook provided by the study of automated electric drive systems enables the staff of those institutions to play an active part in the formation of State technical and economic policy and the development of their country's productive resources.

VII. THE DEVELOPMENT OF THE FERROUS AND NON-FERROUS METALS INDUSTRY ON THE BASIS OF THE DIRECT USE OF ELECTRIC POWER IN TECHNOLOGICAL PROCESSES

About 12 per cent of all the electric power produced in the world is at present used in the electro-thermal and electro-chemical processes connected with the smelting, refining, casting or electrolysis of ferrous and non-ferrous metals.

The technology, nature and economics of electro-thermal and electro-chemical processes used in industry vary widely, as may be seen from the following example.

In the first half of the twentieth century, the production of electric steel was developed in order to satisfy the requirements of the automobile and aviation indsutries for high-grade and super-high-grade steel. It became clear as early as the 1950's, however, that in given conditions the electric steel process could produce ordinary carbon steel cheaper than the open-hearth method.

The economic reasons for this are as follows:

- an electric steel melting plant is 35 to 45 per cent cheaper to build than an open-hearth plant of the same capacity;
- an open-hearth furnace requires a minimum of 45 per cent of pig iron in the charge and cannot take more than 55 per cent of steel scrap, whereas an electric furnace can take a charge consisting of 100 per cent steel scrap and do without pig iron completely - an important saving, as a ton of steel scrap costs only 50 to 60 per cent as much as a ton of pig iron.

The result of this difference in the cost of raw materials, together with the lower depreciation costs on the capital invested, is that even where electric power is quite expensive a ton of electric steel works out cheaper than a ton of open-hearth steel.

There is nothing more wasteful for the economy of a developing country than to sell steel scrap and cast-iron scrap for export and at the same time to purchase required metal abroad. An electric steel melting plant with a capacity of 300,000 tons of steel per year, consuming domestic scrap, pays for itself completely in two years of operation and from the third year onwards shows a substantial profit on every ton of steel melted.

If a country has deposits of coking coal and the economic conditions are favourable to the establishment of a large blast furnace industry with an annual capacity of over 1.5 to 2.0 million tons, then the production of pig iron by blast furnaces is more advantageous than in electric furnaces.

The use of electric smelting processes is backed up by the economics of pig-iron production in countries where there are no deposits of domestic coking coal or where the scale of production of pig iron in a proposed plant does not exceed 450 to 550,000 tons per year, in view of the lower costs for the coke breeze used instead of top-quality blast furnace coke and the lower capital investment in an electric steel melting plant compared with an open-hearth plant.

If a country has complex iron ores which contain not only iron but small quantities of such other useful metals as chromium, nickel, titanium, vanadium or manganese, the processing of such raw material in electric furnaces, which can also extract metals more expensive than iron, becomes even more advantageous economically.

The favourable economics of the electric steel melting process can greatly brighten the prospects for the utilisation of complex iron-ore deposits, considering the high value of the metals which can be extracted as by-products while the steel is being smelted. Only in electric furnaces can all types of ferrous alloys, including ferro-manganese and ferro-silicon alloys, be smelted economically. The financial expenditure on the construction of ferrous alloy production plants is not great, and the export of ferrous alloys is considerably more advantageous than the export of ore or concentrates.

The production of high quality steel, alloys, steels with special physical qualities, and heat-resisting, high-tensile and high-precision alloys, is of great importance in present-day technology. The production and processing of such alloys involves the use of arc and induction vacuum furnaces and equipment for electric slag melting, such as electron beam or plasma arc melting equipment. The electrical industry of the USSR produces all types of vacuum, electronic and plasma installations needed for these purposes.

Over six million tons of aluminium are smelted in the world every year and 120 billion kilowatt hours of electric power are used for this purpose. Many aluminium producing countries operate wholly or partly on imported bauxite. It is clear that the production of aluminium can advantageously be developed in countries where electric power is cheapest.

The production of aluminium begins with the primary processing of bauxite into pure alumina and ends with the electrolysis of aluminium from a molten solution of alumina in cryolite. It involves the setting up of the production of carbon blocks, electrode material and cryolite, as a sideline, and is an industry which requires large amounts of capital and is profitable only when carried out on a large scale.

In the USSR, the production of aluminium from nephelines, with Portland cement as a by-product of alumina production, has been developed to the point where it is economically profitable.

Where raw material (bauxite, cyanites, diaspores and sillimanites) is to be found locally but, for some reason such as lack of financial resources, the production of aluminium cannot be started yet, it is advantageous to establish the production of aluminium silicon or synthetic corundum, both of which can be produced with less expenditure of power and capital investment than aluminium but are more profitable to sell than raw material.

Synthetic corundum is of particular interest. In the USSR a method has been devised and perfected for the single-stage production of synthetic corundum with a content of 98.5 per cent of alumina from bauxite in large electric arc furnaces. This synthetic corundum is vital to the metal industry for the production of high quality refractories and synthetic slags used in steel production.

Sulphide/nickel and copper/nickel ores can most advantageously be smelted into cake in electric furnaces. The power consumption for smelting into cake is about 550 kilowatt hours per tonne of ore. As the nickel content of the raw material smelted is usually 6 to 7 per cent, the total power consumption per ton of nickel contained in the cake is 9,000 - 10,000 kilowatt hours. This consumption of electric power is justified, however, by the high degree of extraction of nickel in electric furnaces. Experience shows that the waste slag from electric furnaces contains 0.25 to 0.30 per cent less nickel than the slag from reverberatory furnaces.

An electric furnace of medium size, melting a thousand tons of ore and concentrates per 24 hour period, produces an extra 2,500 kilogrammes of nickel through the reduction of losses in the waste slag.

The use of electric power in the production of nickel and cobalt enters into almost all stages of the metal-producing process: i.e., into the reduction of nickel, the electrolysis and smelting of cathode nickel and the reduction of cobalt hydroxide.

At all stages of metallurgical production, beginning with the primary treatment of the ilmenite concentrate and ending with the casting of ingots of titanium and its alloys, only electro-metallurgical processes are used.

The total power consumption for all processes involved in the production of one ton of metallic titanium is approximately 70,000 kilowatt hours. It is this that explains the high cost of metallic titanium, for ilmenite concentrate is relatively inexpensive, and readily available.

Setting up a titanium production industry is an extremely complicated matter calling for heavy capital investments. For countries possessing natural resources of ilmenite, the task of setting up such an industry may advantageously be carried out in two stages. The first stage should be limited to the production of titanium-rich sinters containing 75 to 83 per cent of titanium dioxide, as the main product, with the production of pig iron as a by-product to satisfy internal demands for that material. In the second stage, when the possibility of large capital investments arises, progress may be made to the construction of a full set of industrial installations for the production of titanium.

Decisions on the selection of economical methods for the production of zinc, lead and other non-ferrous metals by pyro-metallurgical, electro-metallurgical or electrolytic processes should only be taken after thorough study of the composition of the ores and a review of the country's economic features.

In the Soviet Union, an extensive experimental and research system has been set up for electrothermy. This system makes it possible, after study of a commercial sample of ore, to work out the best technology for its electrothermal processing, to calculate how much the metal will cost when produced, and also to determine the magnitude of the capital investments required to set up an electro-metallurgical metal production industry. This applies not only to metallic ores but also to other types of raw material for the production of phosphorous, calcium carbide, synthetic corundum, carborundum, boron and its derivatives, processed refractories, glass, ceramic enamels, graphite and graphite articles, etc.

VIII. THE ELECTRIFICATION OF RAIL TRANSPORT

Of all branches of electrification, that which has the widest-ranging influence on the economic development of the country is the electrification of rail transport. The effect of electrification of the railway system cannot be calculated simply in financial terms. It gives a new stimulus to the development of industry, and radically changes conditions of work and life. No other type of rail traction can do this.

Only with electrical traction can use be made now of such forms of energy as hydro-electric power, coal, peat, oil shale and other low-calorie forms of solid fuel and, in the future, of wind and tidal power, the difference in temperature between the depths of the earth and its surface and between sea water and air, and solar energy. Statistics show that for every million gross tonne-kilometres the amount of coal required is 48 tons with steam traction (100 per cent), 25 tons with diesel traction (52 per cent), but only sixteen tons with electric traction (32 per cent).

About 60,000 kilometres of railway line have been electrified in the USSR. Great attention is being devoted to the scientific basis of the problems of electrification itself, of rationally organising rail transport operations increasing the traction properties and the power of locomotives, increasing the running speed of trains, and perfecting systems of power supply. The solution of these problems is intimately connected with the level of development of the electrical industry, which produces the entire range of equipment needed for the electrification of rail transport: electric locomotives, transformer installations, protective, switching, starting and control equipment, various types of steelwork and so on. Thus, in this particular case the influence of the electrical industry on the national economy is wide-ranging and affords an active stimulus to its further development.

One of the most radical and complicated scientific questions, which is still as topical as ever, is the selection of the system of electrification to be applied on the railways, for the selection of the correct system of electrification brings the country the greatest economic benefits and sets industry on the road towards the production of the most highly-perfected equipment.

The attention of Soviet scientists and engineers has been [illegible] attracted to two systems of electric traction: one using direct current at [illegible] and the other using alternating current of industrial frequency [illegible].

In 1920, the first of these systems was recommended for the railways of the USSR, and at that time this choice was fully justified.

In the post-war period, however, with the transition [illegible] electrification of the railways, the question of [illegible] current [illegible] electrification of transport assumed particular importance. By [illegible], over 12,300 kilometres of railway line were electrified on the single-phase current system.

The main advantages of the single-phase system are well known, and consist of a considerable cut in the cost of the electricity supply system, mainly through the reduction of the number of traction sub-stations, lower expenditure of non-ferrous metals in the contact system, and [illegible] torque (with consequent improvement in the traction properties of the locomotives through the constant parallel coupling of the motors.

The Soviet Union is a country of boundless expanses, with an enormous quantity of goods transport by rail. Such questions as securing the most economical utilization of power resources, increasing the freight capacity of the railways by increasing the average speed and average weight of freight trains and increasing the labour productivity of railway workers are therefore decisive in maintaining the nation's rapid economic growth.

Table 9 shows the figures for production of main-line electric and diesel locomotives, compared with the progress of railway electrification[1].

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[1] See [illegible] (National Economy of the USSR in [illegible]), pages 113, [illegible]; [illegible] ([illegible]), [illegible], page [illegible], [illegible] 3 February [illegible], [illegible] April [illegible], and 7 August [illegible].

TABLE 9

INCREASE IN PRODUCTION OF MAIN-LINE ELECTRIC AND DIESEL LOCOMOTIVES, COMPARED WITH PROGRESS OF ELECTRIFICATION AND OPERATING FIGURES FOR THE RAILWAYS OF THE USSR

Figures	Year 1940	1950	1958	1960	1961	1962	1963	1964
Production of main-line electric locomotives:								
Number of locomotives	9	102	344	396	557	617	643	[illegible]
Thousands of horsepower	29	333	1445	2062	3024	3479	3655	3693
Average power of each locomotive, in thousands of h.p.	3.2	3.2	4.2	5.1	5.8	5.6	5.6	5.8
Production of main-line diesel locomotives:								
Number of locomotives	5	125	712	1303	1445	1283	1519	1484
Thousands of horsepower	5	170	1424	2613	2944	3015	3133	3145
Average power of each locomotive, in thousands of h.p.	1.0	1.4	2.0	2.0	2.0	2.0	2.1	2.1
Operating length of reconstructed railways, in thousands of kilometres:								
Total	2.2	6.1	20.6	31.5	42.1	53.7	63.1	71.8
Electric traction	1.9	3.0	9.5	13.8	15.7	18.1	20.4	22.5
Diesel traction	0.3	3.1	11.1	17.7	26.4	35.6	42.7	49.3
Freight handled by railways, in billions of tonne-kilometres	415	602	1302	1504	1567	1646	1749	1854
Average number of workers engaged in railway freight operations in the year, in thousands	1300	1710	2080	2010	1990	1970	1970	1980

	1940	1950	1958	1960	1961	1962	1963	1964
Labour productivity of one such worker, in thousands of tonne-kilometres	[illegible]	493	734	[illegible]	877	931	984	1035
Average daily distance covered by locomotives [illegible], in kilometres:								
Electric	[illegible]	[illegible]	497	[illegible]	-	-	586	610
Diesel	356	300	447	[illegible]	-	-	504	518
Steam	255	243	302	317	-	-	315	321

As a result of the reconstruction carried out on the basis of railway electrification, the number of personnel employed on rail freight operations has remained practically unchanged over the past five years, and the entire increase in the amount of freight transported has been due to the improvement in labour productivity.

In 1964, the average weight of an electrically-hauled freight train was 40 per cent greater than with steam traction, while the average distance covered by an electric locomotive in a day was 90 per cent greater than that of a steam locomotive in a similar period.

The developing countries have an extremely feeble railway network with a permanent way construction which allows axle loadings of the order of only 10 to 15 tons, and the density of their railway systems can be ten or, in some cases, even hundreds of times less than in industrially developed countries. The total length of the railways of Africa, Asia and South America at the beginning of 1960 was something over 300,000 kilometres, and these railways had eighteen different wheel gauges, varying from 597 to 1,676 millimetres.

The gap between the level reached by the capitalist countries and that reached, for example, by Africa in 1960, is illustrated by the following figures: for Africa as a whole the density of the railway system was only 0.24 kilometres per 100 square kilometres of territory, while in capitalist countries it was 1.04 kilometres. In such African countries as Algeria, Congo (Kinshasa), Kenya, Uganda and Tanganyika the railway density was 0.2 kilometres; in Ethiopia, Sudan, Senegal, Mali and Cameroon, only 0.1 kilometres; while in the Congo (Brazzaville), the Central African Republic, Gabon and Chad it was only 0.02 kilometres, i.e. 50 times lower than in the rest of the world and 250 times lower than, for example, France.

At the same time, the economies of these countries are passing through a period of relatively intensive growth, chiefly due to their efforts to exploit their great natural resources (mainly of raw materials); and the fact that the loads to be carried consist largely of raw materials means that there are even higher demands on the freight-carrying capacity of the rolling stock. The lightness of the permanent way, the low technical standard of the locomotives, the low running speeds and the small permissible axle loadings, together with the fact that the majority (67 per cent) of the lines are narrow gauge, all greatly complicate the solution of transport problems, which hinder the normal and harmonious development of the economy even at this primary stage of development.

Between 1958 and 1963, the newly independent countries developed their productive capacity and succeeded in increasing the volume of their industrial production one and a half times, development being most intensive in the manufacturing industry (which grew 1.72 times), including the metal industry (which grew 1.52 times); transport operations play a vital part in the production processes of both these branches of the economy. The production of electric power, for its part, increased by 59 per cent.

According to the data of the statistical monthlies of the United Nations, the growth of heavy industry has outstripped other developments, and in particular there has been a failure to keep up with the requirements for means of transport. A vivid illustration of this situation is provided by India, where for years industrial development has been held back by shortages of electric power and transport. In 1962, the amount of freight handled on the Indian railways increased by only 2.7 per cent, while industrial production grew by 8 per cent, but in 1963 transport modernisation, with the electrification of a number of important main-lines and other measures to increase the freight-carrying capacity of the railways, enabled 11 per cent more freight to be carried while the production of electric power increased by 14.4 per cent.

These difficulties are intensified by the excessive diversity of structure, the weakness, and in some cases even the total absence of a proper fuel and power basis in developing countries, most of which are characterised by a deficit of solid or liquid fuel while at the same time possessing great hydro-electric power resources. For Africa alone (excluding the Republic of South Africa) the hydro-electric power resources are sufficient to operate electric power stations of a total capacity of 1,150 million kilowatts, with a total production of electric power over 5,000 billion kilowatt hours. At the same time, the actual total production of hydro-electric power in Africa in 1960 was no more than 1.5 billion kilowatt hours, or only 1.6 per cent of the total consumption of primary forms of power and only 8.8 per cent of the total amount of electric power produced.

For the economies of the developing countries it is extremely important to keep such a structure of the fuel-power balance as will make them independent of fuel imports (this applies in particular to petroleum and petroleum products). Consequently, for countries which do not possess their own petroleum resources and lack the production facilities for refining diesel fuel, the most rational way of developing the transport system can only be electrification, which enables them to use for traction purposes electric power produced either in thermal power stations using local fuel such as coal, peat or oil shales, or in hydro-electric stations. As experience has shown, the Republic of India, having selected electrification with single-phase alternating current at industrial frequency as the main method of improving its railway system (as in the USSR, France, the United Kingdom, Japan and other countries), is now free of the need to import petroleum products for diesel locomotives.

Electric traction has also proved to be the most economical solution in the conditions prevailing in the Republic of India, where two million ton/kilometres of the freight transported by rail each year are carried on lines with steep gradients and six to seven million ton/kilometres on flat sections.

Where the density of the railway system is not very high, and where the nature of the permanent way does not permit the use of modern heavy rolling stock, it is advisable to use rolling stock with a high motor power on each axle but a relatively low axle loading. Such properties are possessed by modern electric locomotives, which may be fitted with traction motors of a power of up to 1,100 - 1,200 kilowatts per axle.

When selecting the form of traction to be used by developing countries, account must be taken of the features which are most important to the national economy, such as reliability of operation of any given type of locomotive; simplicity of design; simplicity of servicing and operation; range without refuelling; performance attained in acceleration from rest, braking and maximum speed; a sufficient reserve of power and ability to operate safely even when overloaded; specific power-weight ratio; ability to accommodate a sufficiently high power in a given area or space; suitability for high-altitude operation; constant readiness for service; low axle loading, with minimum dynamic co-efficient; and a sufficient level of cleanliness to guarantee healthy working conditions.

The problems of selecting the best type of rolling stock for the railways of developing countries were clearly brought out at the Fourth African Railway Conference in Addis Ababa in 1966. Study of the experience gained in the operation of rolling stock on the lines of the majority of African countries shows that in most cases the upper limit of the axle loading is in the region of 15 tons, which, for a four-axle diesel locomotive, yields a maximum installed power of 1,000 horse-power or, for a six-axle diesel locomotive, a power of 1,500 horse-power. Consequently, for diesel locomotives the power selected is generally between 500 and 600 horse-power, depending on the height of the place of operation above sea level. Such figures for power and axle loading bear witness to the serious difficulties of laying heavier rails and strengthening the permanent way, both of which are essential to cope with the growing volume of freight to be carried.

This underlines once again the advantages to be gained from using electric traction, particularly in view of the low permissible axle loadings. An elementary calculation shows that for a given rail gauge and a given strength of permanent way, electric traction can give tractive powers 1.8 to two times greater than diesel traction.

IX. THE ELECTRICAL INDUSTRY - THE TECHNICAL BASIS FOR THE ELECTRIFICATION OF AGRICULTURE AND OF THE DAILY LIFE OF THE POPULATION

In our country the electrification of agriculture was begun only after the victory of the great October Socialist revolution. In the rural areas of pre-revolutionary Russia there were only 78 small electric power stations with a total capacity of about 2,000 kilowatts, most of which belonged to large landowners.

The rural population, which in 1913 made up 82 per cent of the entire population of the country, lighted their dwellings with wooden torches and kerosene lamps. The main motive power in the peasant economy was provided by beasts of burden. At the beginning of 1917, beasts of burden (when their efforts were expressed in terms of mechanical force) accounted for 23.7 million horse-power or 99.2 per cent of all the power resources available to the rural population, while small mechanical power sources and electrical installations accounted for only 0.8 per cent.

Only with the setting up of a great national electrical industry was it possible to begin work on the electrification of agriculture. During the period 1954-1965 the length of rural electric transmission lines operating at 20-10-6 kV and of low-voltage electric lines operating at 0.4 kV reached 1.7 million kilometres, while in 1965 the consumption of electric power in agriculture amounted to 21.4 billion kilowatt hours. There was a considerable increase in the extent to which electric power for collective farms and State farms was supplied from the most reliable sources - State power systems and central electric power stations. In 1970, Soviet agriculture will consume 60 to 65 billion kilowatt hours of electric power, 80 to 90 per cent of this from State power systems and large central power stations. This means that the absolute majority of agricultural production units will be supplied with electric power, and the closing of some 50,000 small private thermal electric power stations will enable about 100,000 workers to be released for other work.

The mechanization of production processes through the use of systems of electrified machines and equipment permits the most rational solution of the problem of raising labour productivity. It is calculated that every kilowatt hour of electric motive power used in agriculture gives a saving of 1.5 to two man-hours.

Electric power can most economically be used in agricultural production in large processes which require a stationary source of power. Such processes play a decisive role in stock-breeding, poultry-breeding, primary processing of grain and other industrial crops, irrigation and also in auxiliary agricultural enterprises. In the electrical milking of cows, for example, the expenditure of labour is reduced by 67 per cent compared with hand milking, while the operating costs are reduced by 34 per cent. The electro-mechanical distribution of food on pig farms reduces labour expenditure by 95 per cent compared with hand distribution and yields a 96 per cent reduction in operating costs. Electro-mechanical water supply and distribution on stock-breeding farms gives a reduction of 96 per cent in expenditure of labour compared with methods involving the use of horse-drawn transport and manual labour, and gives a 90 per cent reduction in operating costs. The electrification of the cleaning and sorting of grain gives a 30-35 per cent saving in labour expenditure compared with mechanical methods and an 18-35 per cent reduction in operating costs. Finally, the use of electric motive power for irrigation brings about a saving of 20-30 per cent in labour expenditure compared with mechanical motive power, and a 15-25 per cent saving in running costs.

Present tendencies are towards a transition from the mechanisation of individual processes to the complete mechanization, on the basis of electrification, of the whole cycle of operation connected with a particular crop or branch of agriculture. The most important cycles of operations, the electrification of which secures maximum efficiency, are the following:

In stock-breeding:

The supply of water to stock-breeding and poultry-breeding farms;

The preparation and distribution of food;

The removal of manure;

The milking of cows and the primary processing of milk;

The shearing of sheep; and

The collection and packing of eggs.

In arable farming:

The irrigation of fields;

The cleaning, sorting, drying and grinding of grain;

The primary processing of cotton and other crops, and the preparation of hay meal.

Electric power is also used in auxiliary agricultural undertakings such as mechanical repair workshops and woodworking shops.

The resources of electro-technology open up great possibilities for the automation of agricultural production on a scale which cannot be attained through mechanical means of using electric power. Electro-technology permits the agricultural use of such resources as light, high-frequency currents, ultrasonic power, and other forms of power for direct action on animals and plants in order to accelerate their growth, reduce losses due to disease, etc., and so forth.

In addition to the purely economic advantages gained through the wide electrification of agriculture, one must also consider the social aspects of the matter. The electrification of extensive rural areas enables broad sections of the population to enjoy the advantages of present-day culture and knowledge.

The technical re-equipment of agriculture on the basis of electrification can be carried out only if there is a sufficiently highly developed electrical industry. Because of the great length of the low-power transmission lines involved and the large number of consumers of electricity, with at the same time a low concentration of power consumption, agriculture is an extremely heavy consumer of such electrical goods as electric motors, transformers and complete distribution systems, starting and protective apparatus, lighting equipment and electric cable.

In the twenties, which were the darkets days for Russia, V.I. Lenin said that "the introduction of electric light and electric heating into every home will free millions of 'household slaves' of the need to pass three-quarters of their lives in a stinking kitchen"[1/]. These words pin-point the revolutionary role which electricity can play in radically changing not only working and living conditions, but indeed the whole existence of the people.

The level of economic development of a State and the material well-being of its people are largely characterised by the amount of electric power used for communal and public needs. In 1965, out of 507 billion kilowatt hours of electric power produced in the USSR, over 120 billion were used for lighting and the social and communal needs of the workers.

Domestic machines and appliances driven by electricity now occupy a firm place in the daily life of the Soviet people, and about 400 enterprises in the USSR are engaged in their production. In the creation of new designs and models of domestic electrical appliances and the organisation of their mass production a leading role must of necessity be played by the factories of the electrical industry, in which almost the whole range of domestic electrical machines and appliances is produced.

The range of electrical goods produced in the USSR for domestic purposes covers hundreds of items (over 1,000 models). The annual output of refrigerators, washing machines, vacuum cleaners, electric irons, electric stoves and a number of other domestic appliances is higher in the Soviet Union than in any country in Western Europe, and for certain individual articles it is as high as

1/ V.I. Lenin, fourth edition, volume 19, page 42.

that of the United States of America. In 1965, 3,429,000 washing machines, 1,675,000 refrigerators and 800,000 vacuum cleaners, and a large quantity of electric floor polishers, electric irons, electric shavers, etc. were produced for the population of the USSR.

The use of modern electric household machines and appliances enables the time spent on housework to be approximately halved. The annual saving of time on housework for a family of four persons, including two children, amounts to 1,600 man-hours. For a housewife, this does not mean just a daily saving of several hours, but liberation from hard physical tasks, a healthier life, and a chance to broaden her interests and knowledge. These advantages cannot be gauged by any systems of measurements or units.

From the production of individual machines and appliances for domestic use, a transition is now taking place in the USSR towards the development and production of complete electrical equipment for the home: that is to say, complete sets of indoor electrical equipment, lighting fittings, and radio and electronic apparatus. The "kitchen" set of appliances, for example, consists of an all-purpose kitchen machine, a refrigerator, a dishwasher, an electric stove with an electrical oven and a filter-equipped fan, and other equipment. Work on the complete electrification of dwellings has already begun in many cities of the USSR, such as Vladivostok, Krasnoyarsk, Mirny and others. In the new buildings of these cities, heating, hot water supply and the preparation and refrigeration of food are all carried out by electricity, so that the persons living in these new buildings enjoy all the conveniences and comforts created by electrical appliances.

I. PROSPECTS FOR THE DEVELOPMENT OF THE ELECTRICAL INDUSTRY; THE DEVELOPMENT OF SCIENCE

In preceding sections of this paper it was noted that there is no branch of the productive sector which so determines the level of economic development of any given country as power engineering and its technical basis: the electrical industry.

The economy of the world is extremely varied. The nations of the world exploit the basic forms of energy in different ways. If an attempt were made to equal within 10 to 15 years in every other country the electric power production and consumption of, for example, the United States of America today, it would be necessary to build electric power stations with a total capacity of 3 billion kilowatts or, taking into account the increase in population, to bring into operation about 300 million kilowatts of generating power every year. The installed capacity of all the electric power stations in the world today comes to approximately 600,000,000 kilowatts. This would mean, then, that in two years it would be necessary to build as many electric power stations as have been built and equipped in the last hundred years.

Such an undertaking is obviously unrealistic, but this extreme example does vividly show the infinite possibilities of developing electric power production throughout the world.

The experience gained in the electrification of the national economy of the USSR usefully illustrates the possibilities of accelerating this process. Thus, if we compare the rates of increase of the production of electric power in the USSR and in other highly developed countries over a twenty-year period (from 1937 to 1957), we see that the rate of increase in the production of electric power in the USSR was 1.2 times higher than in the USA, 1.5 times higher than in the Federal Republic of Germany, 1.6 times higher than in the United Kingdom, twice as high as in France, and 2.1 times higher than Japan. Nor must it be forgotten that for the USSR the years 1937-1941 were fraught with pre-war tensions, while the years 1941-1945 coincided with the Second World War.

This rapid development of power engineering and of the electrical industry is due to the thorough exploitation of the latest achievements of technology and to the practical utilisation of inventions, discoveries and achievements in both the electrical field and adjoining branches of technology.

Prospecting to discover new deposits of minerals is being carried out on an ever-increasing scale. The question which arises in this connexion, however, is not that of the exhaustion of reserves of minerals, but that of satisfying mankind's increasing needs for power in general and cheaper power in particular. The latest discoveries in the fields of physics, chemistry and electricity have brought nearer the real possibility of obtaining more electric power not by burning organic fuel in the boilers of electric power stations of the condenser type, but through increasing the efficiency of electric power installations to 60 to 65 per cent, using nuclear fuels such as uranium and thorium, using magnetic hydro-dynamic methods, and obtaining electric power directly from fuel elements, with the aid of powerful solar batteries.

The search for new and cheaper methods of generating electric power is closely connected with the problem of the economical transmission of electricity over long distances. Long-distance alternating-current transmission lines operating at voltages of 500,000 and 750,000 volts have already been established, and lines for the transmission of electricity at 1,200,000 volts are in the design and development stage. These developments permit the economical transmission of large amounts of electric power over distances of more than 1,000 kilometres. For extremely long-distance power transmission lines, the best prospects appear to lie in the transmission of direct current at a voltage of up to 1.5 million volts. The greatest difficulties in the establishment of such transmission lines are connected with the construction of reliable inverters to rectify the alternating current supplied by the turbo-generators and then change the direct current back into alternating current of industrial frequency. One possible solution to this problem is to use the phenomenon of superconductivity and to transmit large amounts of electric power through tubes containing liquid helium and nitrogen at a voltage of approximately 75,000 volts, that is to say, close to that at which the electricity is generated. Even at the present cost of superconductive materials, such lines could, at a preliminary estimate, compete with 750,000 volt alternating current lines or 500,000 volt direct current lines. Inverters would, of course, be necessary at each end of the line in this case also, but there is no problem here of super high voltages.

In this branch of electricity another radically new system has been discovered, the essence of which is the transmission of electric power with the aid of quantum amplifiers and generators. These amplifiers and generators operate on the principle of the auto-oscillation processes produced in atoms of ionised gas and in the atoms of the crystal lattice of special materials which are exposed to powerful short-wave electro-magnetic radiation in the infra-red and ultra-violet areas of the spectrum. This principle makes it possible to concentrate the electric power which is being transmitted into an extremely narrow ray. The successful solution of the problems connected with this system will bring about revolutionary changes in the practical transmission of electric power.

[illegible] further systematic [illegible] ... [illegible] strong ... [illegible] production ... [illegible] ...

[illegible] Science and ... [illegible] industry ... the [illegible] and [illegible] centuries ... [illegible] extremely small ... [illegible] many branches of the economy.

[illegible] the utilisation of conventional [illegible] producing power [illegible] ... of power. [illegible] study and utilisation [illegible] installations that the difference [illegible] becoming more conventional. [illegible] after the physical [illegible] of the [illegible] experimental installations. Therefore theory, which [illegible] the way to experiment, is now showing the way to industrial practice [illegible] becoming [illegible] productive force in its own right.

The development of [illegible] electrical industry [illegible] the technical basis for electrification [illegible] for every country. The establishment of such an industry is [illegible] the foundation for the successful development of a country's own productive resources but is also in keeping with the need for general participation in the task of paving new ways to the solution of power problems all over the world.

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