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INTELLIGENCE REPORT

CONSUMPTION OF ELECTRIC POWER
BY THE NUCLEAR MATERIALS INDUSTRY
IN ANGARSK, IRKUTSKAYA OBLAST, USSR

⋮
DIRECTORATE OF INTELLIGENCE

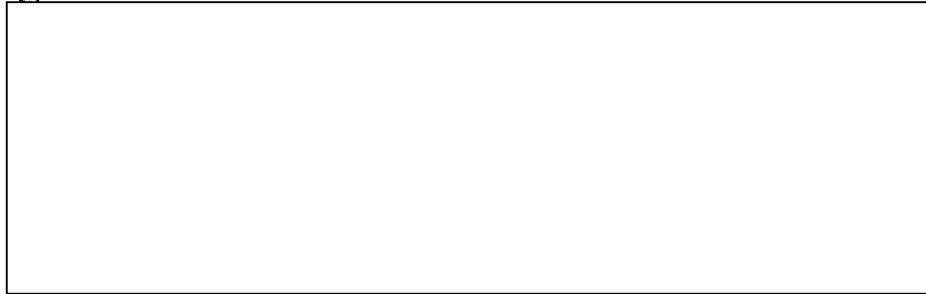
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FOREWORD

This report includes estimates of the amount of electric power consumed by the Angarsk Gaseous Diffusion Plant and by production of an unknown nuclear product in the Angarsk Synthetic Fuels Combine 16. Inputs of electric power to facilities for production of nuclear materials form one of the most important considerations in making estimates of production of nuclear materials. The report utilizes information on production of electric power in Irkutskaya Oblast and on consumption of electric power by nonnuclear installations to estimate as a residual the amount of electric power utilized in production of nuclear materials. Although estimates obtained in this fashion are subject to substantial margins of error, perhaps as much as 15 percent, it is believed that the quantities are sufficiently accurate to provide useful measures of the electric power consumed by the nuclear materials industry at Angarsk.

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CONSUMPTION OF ELECTRIC POWER
BY THE NUCLEAR MATERIALS INDUSTRY
IN ANGARSK, IRKUTSKAYA OBLAST, USSR*
1954-65

Summary and Conclusions

During the last decade a well-integrated power system has been developed in Irkutskaya Oblast primarily to serve the rapidly growing demands for electric power of a nuclear materials industry in Angarsk. It is estimated that an unidentified section of Angarsk Synthetic Fuels Combine 16 started consuming electric power in 1954. Although the evidence is not conclusive, this section is believed to be producing nuclear materials. Consumption of electric power by this section had grown to 0.8 billion kilowatt-hours (kwh) by 1957.

The largest consumer of electric power in Irkutskaya Oblast, however, is the Angarsk Gaseous Diffusion Plant, which is estimated to have started consuming power in the fall of 1957, when power was first sent over 220-kilovolt (kv) transmission lines from the Irkutsk GES** to the diffusion plant. The supply of power to the diffusion plant increased in the fall of 1959, when the on-site Angarsk TETs***10 went into operation. Further increases in the supply of power to the diffusion plant occurred in 1962, when new transmission lines were constructed from Bratsk to Angarsk. It is estimated that in mid-1963 the load drawn by the diffusion plant reached about 1,790 megawatts (mw) and that it has remained at this level since that time. The firm supply† of electric power to the diffusion plant, estimated to be about 2,500 mw in mid-1964, is more than adequate to cover this load. About 1,040 mw of the load is currently met by the Bratsk GES and 750 mw by TETs 10.

* The estimates and conclusions in this report represent the best judgment of this Office as of 15 September 1964.

** Gidroelektricheskaya stantsiya (hydroelectric powerplant).

*** Teploelektrotsentral' (heating and powerplant).

† Firm supply is the amount of electric power that would be available to cover peak load even if the largest single source of power were out of commission.

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The consumption of electric power by the Angarsk Gaseous Diffusion Plant for the calendar years 1957-65, the peak load at the beginning of the year, and the power for cascade pumping for the year ending 30 June, are estimated as shown in the following tabulation:

| <u>Year</u> | <u>Consumption (Billion KWH)</u> | <u>Peak Load (MW as of 1 January)</u> | <u>Power for Cascade Pumping (Thousand Megawatt-Days for the Year Ending 30 June)</u> |
|-------------|--------------------------------------|---|---|
| 1957 | 0.2 | 0 | 0 |
| 1958 | 2.3 | 120 | 44 |
| 1959 | 3.3 | 360 | 119 |
| 1960 | 5.4 | 525 | 182 |
| 1961 | 7.1 | 690 | 252 |
| 1962 | 9.8 | 1,035 | 355 |
| 1963 | 14.0 | 1,365 | 491 |
| 1964 | 14.9 | 1,790 | 624 |
| 1965 | 14.9 | 1,790 | 624 |

The estimates of consumption indicate peak load and amounts of power for cascade pumping in excess of those used in deriving existing estimates of production at the Angarsk Gaseous Diffusion Plant.

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I. Introduction

In 1952, Irkutskaya Oblast was still an undeveloped region. Relatively small local industries relied on local powerplants, and there was no transmission network. Only the cities of Irkutsk, Cheremkovo, Angarsk, and Usol'ye were significant consumers of electric power. Among these, the largest consumer was the city of Irkutsk, which contained machine building and aircraft plants and most of the food and light industries of the oblast. Cheremkovo was the center of the coal mining industry. Angarsk did not exist until 1948 and first became important when Synthetic Fuels Combine 16 was placed in operation in 1952. Usol'ye contained only a small chemical industry. Apart from these towns, smaller centers of production and consumption of power were scattered throughout the oblast, each with its own small powerplant serving motor vehicle and railroad repair shops, sawmills, and other local industry.

Since 1952 a well-integrated power system has developed in Irkutskaya Oblast, primarily to serve the rapid growth of a nuclear materials industry at Angarsk. Some small inefficient powerplants still exist in Irkutskaya Oblast outside the power system, but their relative importance will continue to decline as radial transmission lines are extended to outlying areas. The first stage of the development of the nuclear materials industry in Angarsk was a power-intensive section of Angarsk Synthetic Fuels Combine 16 that may produce heavy water. The principal nuclear materials enterprise in Angarsk, and the largest consumer of electric power, is the Angarsk Gaseous Diffusion Plant, which probably is the largest consumer of power among the four plants in the USSR for the separation of U-235.

II. Growth of the Irkutsk Power System

A. Capacity

The development of power-generating facilities in Irkutskaya Oblast has been more rapid than in any other region in the USSR. This rapid development was necessary to keep pace with growing industrial demands, principally those of the nuclear materials industry. Most of this development has taken place within the Irkutsk Power System and has been concentrated in a few large powerplants. Of the more than 1,100 powerplants scattered throughout the oblast at the end of 1963, nine plants in the Irkutsk Power System had a combined capacity of about 5,800 mw -- approximately 95 percent of the total

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installed generating capacity of 6,100 mw in the oblast. Expansion of existing powerplants and the startup of three new thermal electric powerplants will bring the total capacity of the Irkutsk Power System to about 6,600 mw by the end of 1965. Connected to the Irkutsk Power System, but administratively not a part of it, are powerplants that primarily serve local industries and provide some backup for the transmission network. These powerplants have a combined capacity of about 60 mw. In addition, there exists in the oblast about 240 mw of capacity in powerplants, not connected to the Irkutsk Power System, that serve diverse activities such as agriculture, mining, and timber camps. The capacity of these plants may increase to about 250 mw by 1965.*

The Bratsk GES, with an installed capacity of 3,600 mw, and Angarsk TETs 10, with an installed capacity of 1,000 mw, are the two principal sources of power for the Angarsk Gaseous Diffusion Plant. In the next 2 years the capacity of the Bratsk GES will be increased to a level of 4,050 mw. Two other large powerplants -- Angarsk TETs 1, with a capacity of about 300 mw, and the Irkutsk GES, with a capacity of 660 mw -- supplied most of the electric power for the Irkutsk Power System and for the nuclear materials enterprises until Angarsk TETs 10 became an important supplier in 1960.

B. Production

Production of electric power in Irkutskaya Oblast grew from 660 million kwh in 1951, before the start of significant development of power in the oblast, to 22.6 billion kwh in 1963. It is estimated that production of electric power will reach 28 billion kwh in 1965.**

In 1963 the Bratsk GES is reported to have produced 7.9 billion kwh and the Irkutsk GES, 4.0 billion kwh. It is estimated that production at Angarsk TETs 1 was about 1.9 billion kwh and at Angarsk TETs 10 about 7.0 billion kwh. Other powerplants of the Irkutsk Power System produced another 1.1 billion kwh, and powerplants outside the power system produced 0.7 billion kwh. The most significant increase in production in 1964 and 1965 will be at the

* For estimates of the end-of-the-year capacity of powerplants connected to the Irkutsk Power System and the total capacity of Irkutskaya Oblast for each year of the period 1950-65, see Table 1, Appendix A.

** For estimates of the annual production of electric power in powerplants in the Irkutsk Power System and in Irkutskaya Oblast for each year of the period 1950-65, see Table 2, Appendix A.

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Bratsk GES, expected by the USSR to produce 11 billion to 12 billion kwh in each of these years.

C. Transmission Network

Power transmission lines have been constructed in Irkutskaya Oblast during the past decade to connect the major powerplants of the Irkutsk Power System with the principal power-consuming centers. Transmission lines have expanded from a single-circuit 110-kilovolt (kv) line, 50 kilometers (km) long in 1952, to a complex network of 110-kv, 220-kv, and 500-kv lines traversing about 800 km in the southern part of Irkutskaya Oblast in 1964. The lines generally are parallel to the Trans-Siberian Railroad, with important connections extending north to Bratsk.

Construction of the transmission network has progressed in a sequence that allows most of the production of the three largest powerplants to be channeled to the Angarsk Gaseous Diffusion Plant.* Significant amounts of power began to be supplied to the diffusion plant late in 1957, when two 220-kv lines were placed in operation between the Irkutsk GES and Substation 1 of the diffusion plant. For a couple of years these lines were supplemented only by 110-kv connections to the Irkutsk GES and Angarsk TETs 1. Angarsk TETs 10, built specifically to supply the diffusion plant, began to supply power to Substation 2 of the diffusion plant over a new set of 110-kv lines in the fall of 1959. Beginning in 1962 the Bratsk GES began to supply most of the power it generated to Substation 1 of the diffusion plant over two 500-kv lines. One 500-kv line from the Bratsk GES to Substation 1 was placed in operation in January 1962, and the second line in December 1962. The first of these lines operated at 220 kv until it was converted to 500 kv in February 1963. The second line was being converted to 500 kv in December 1963. Additional power also can be supplied to the diffusion plant over 220-kv transmission lines from the Bratsk GES and from Usol'ye TETs 11.

Additional transmission lines have been built in Irkutskaya Oblast to supply other consumers. A double 110-kv line has been constructed along the Trans-Siberian Railroad from Slyudyanka to the border of Krasnoyarskiy Kray. A 220-kv line has been built from

* For the general alignment and capacity of main transmission lines serving Angarsk and Irkutsk as of the end of 1964, see the map, following p. 6.

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Substation 1 of the Angarsk Gaseous Diffusion Plant to the Irkutsk Aluminum Plant. Another 220-kv line has been built from the Irkutsk GES to the Irkutsk Aluminum Plant and is being extended along the Trans-Siberian Railroad to Ulan-Ude in Buryatskaya ASSR. This line and the recently completed 500-kv line from Bratsk to the Krasnoyarsk Power System will permit significant amounts of power to be exported from Irkutskaya Oblast starting in 1964.

III. Consumption of Electric Power

A. By Nonindustrial Sectors of the Economy*

The amount of electric power that could be supplied over transmission lines to the Angarsk Gaseous Diffusion Plant is far in excess of the actual supply. Actual consumption of electric power by the diffusion plant has been estimated as a residual by deducting estimated consumption by other consumers from total production.

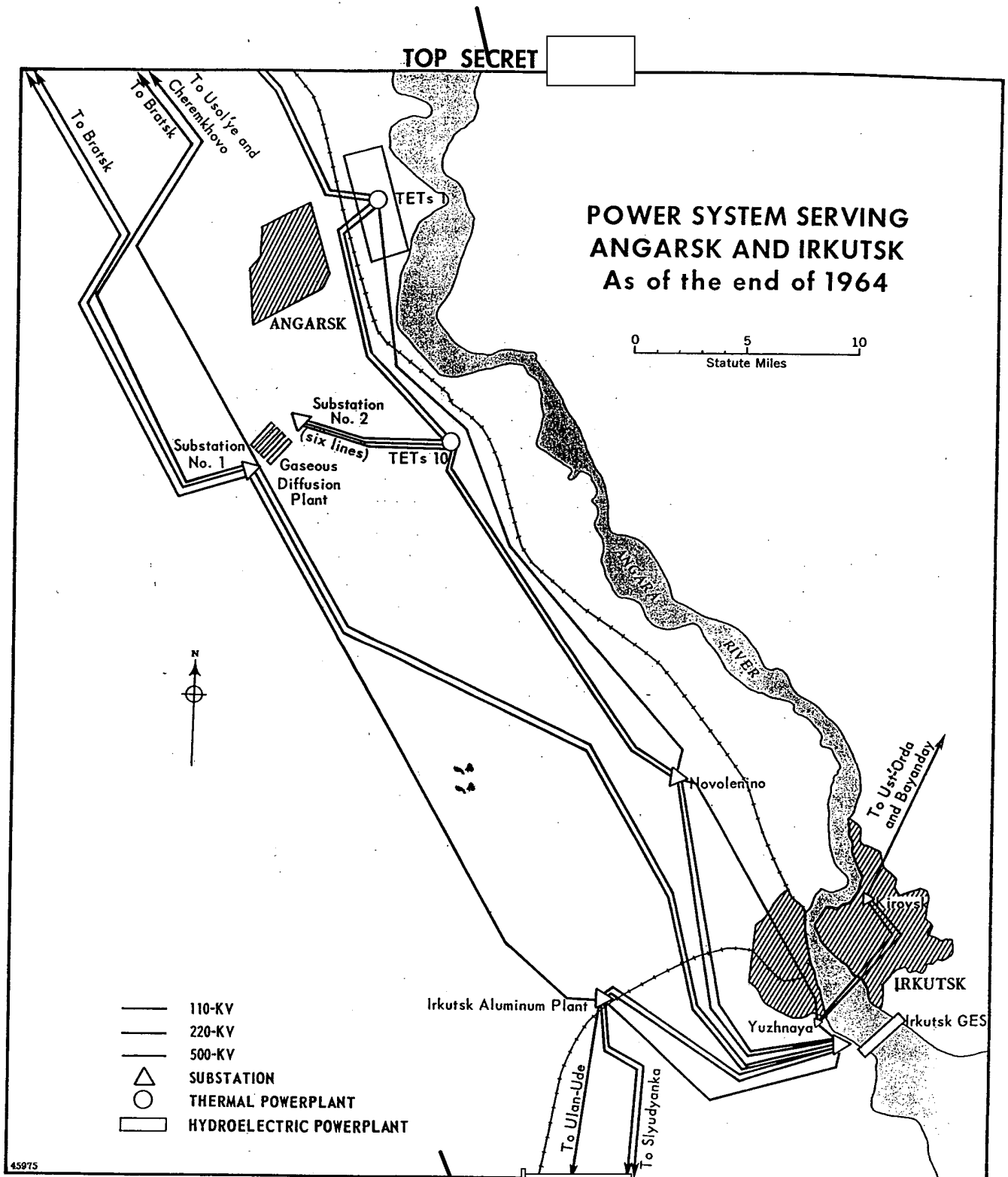
All the electric power produced in Irkutskaya Oblast was consumed in the oblast until 1962. In that year an estimated total of 100 million kwh was sent over 110-kv lines to Krasnoyarskiy Kray for use by the electrified Trans-Siberian Railroad. Late in 1963 a 500-kv transmission line was placed in operation at 220 kv between Bratsk and the Kamala substation in Krasnoyarskiy Kray. This line extends through Krasnoyarskiy Kray to Kemerovskaya Oblast and will permit exports of electric power from Irkutskaya Oblast to increase to a level of about 1.6 billion kwh in 1964.

The largest nonindustrial consumer of electric power in the oblast is the electrified Trans-Siberian Railroad, which in 1963 used about 1.3 billion kwh. It is estimated that all other nonindustrial consumers of electric power in the oblast (construction, transportation other than the electrified Trans-Siberian Railroad, communal and living needs of urban centers, and the rural economy) used about 0.8 billion kwh in 1963. Consumption of electric power per capita in these categories in the Irkutskaya Oblast is about average for the USSR.

* For estimates of consumption of electric power by various categories of consumers in Irkutskaya Oblast for each year of the period 1950-65, see Table 3, Appendix A. For an explanation of the methodology used to estimate consumption, see Appendix B.

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The electric power industry in Irkutskaya Oblast is itself a large consumer of electric power. It is estimated that in 1963 the industry used close to 0.9 billion kwh in its own powerplants and suffered losses of 1.5 billion kwh in moving electric power over the transmission lines.

B. Angarsk Synthetic Fuels Combine 16

During the years 1952-57 the largest consumer of electric power in Irkutskaya Oblast was Angarsk Synthetic Fuels Combine 16, originally designed as a synthetic fuels plant using equipment removed after World War II from a German coal hydrogenation plant. TETs 1 was built to supply the combine with electric power. Although the first section of the combine probably was constructed according to original designs, it has been greatly modified since 1954, and a second section has been built. The combine now uses primarily crude petroleum as raw material and emphasizes production of petrochemicals rather than synthetic gasoline. It is estimated that the combine was using about 90 million kwh for production of an assortment of petroleum and chemical products by 1956 and that this consumption had grown to about 340 million kwh by 1960.* Because investment in the combine has continued since that time, consumption may grow to 800 million kwh in 1965.

Starting in 1954, a special section of Combine 16 began to consume large amounts of electric power. The exact nature of this special section is not known, but because some part of Combine 16 was subordinate to the Ministry for Medium Machine Building (which is responsible for nuclear materials), it has been estimated that the special section is engaged in producing nuclear material. The nuclear material involved may be heavy water, although there is no direct evidence for this conclusion. Consumption of electric power by the special section is estimated to have reached 440 million kwh in 1955 and to have been double that amount by 1957.

It is estimated that Combine 16 as a whole is using all the electric power made available by TETs 1, so that the TETs is not a significant supplier of power to other consumers.

* For estimates of the annual consumption of electric power by Combine 16 during the years 1950-65, see Table 3, Appendix A.

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C. Industrial Consumers of Electric Power Not Connected with Production of Nuclear Materials

Industrial consumers of electric power not connected with the nuclear materials industry in Irkutskaya Oblast have increased consumption of electric power steadily throughout the entire period. Major new consumers of electric power, and their initial years of operation, have been as follows: the Angarsk Cement Plant, 1958; the Angarsk Petroleum Refinery, 1960; a new section of the Usol'ye Chemical Combine, 1961; and the Irkutsk Aluminum Plant, 1962. It is estimated that the latter plant will consume 1.8 billion kwh in 1964, which is more than will be consumed by Combine 16.

In spite of the rapid growth of consumption of electric power in Irkutskaya Oblast by various nonindustrial sectors of the economy, by all sections of Combine 16, and by industrial consumers not associated with the nuclear materials industry, a residual of electric power, not accounted for by these consumers, has been growing rapidly since 1957. This residual, which had reached more than 55 percent of the power produced in the oblast in 1964, is the power consumed by the Angarsk Gaseous Diffusion Plant.

IV. Consumption of Electric Power by the Angarsk Gaseous Diffusion Plant

A. Rapid Growth of Consumption

By far the largest consumer of electric power in Irkutskaya Oblast and in the entire USSR is the Angarsk Gaseous Diffusion Plant. It is estimated that this plant started operation at about the time that the first 220-kv transmission line was placed in operation from the Irkutsk GES to Substation I of the diffusion plant in October 1957. An estimated power balance of Irkutskaya Oblast indicates that the plant used about 0.2 billion kwh in the remainder of 1957, 2.3 billion kwh in 1958, and increased consumption rapidly thereafter until it used about 14 billion kwh in 1963 and nearly 15 billion kwh in 1964. It is estimated that consumption will remain at about this level through 1965.*

* For estimates of the consumption of electric power by the Angarsk Gaseous Diffusion Plant for each year of the period 1957-65, see Table 3, Appendix A.

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This rapid growth of consumption has been accompanied by an even more rapid growth of the firm supply of power. It is estimated that firm supply always has been substantially in excess of the peak load, as is shown by the following comparisons of peak load* and firm supply** at times when successive stages of growth in power consumption were completed:

| | <u>Megawatts</u> | |
|-------------|------------------|--------------------|
| | <u>Peak Load</u> | <u>Firm Supply</u> |
| End of 1958 | 360 | 410 |
| Mid-1960 | 690 | 770 |
| Mid-1962 | 1,160 | 1,600 |
| Mid-1963 | 1,790 | 1,900 |

Firm power supply as of mid-1964 and 1965 is estimated at about 2,500 mw -- 40 percent higher than the estimated peak load of 1,790 mw.

It is estimated that electric power for cascade pumping at the Angarsk Gaseous Diffusion Plant has grown from 44,000 megawatt-days in the year ending 30 June 1958 to 624,000 megawatt-days in the year ending 30 June 1964 and that it will remain at this level at least through 1965. ***

* For estimates of the monthly load and consumption of electric power by the Angarsk Gaseous Diffusion Plant, see Table 4, Appendix A. These estimates are derived from and are consistent with the estimates of annual consumption. They are presented not as exact estimates but as orders of magnitude that can be compared with estimated firm supply at successive points in time. Comparison of estimates of peak load and firm supply in this fashion offers the best check on the accuracy of the estimates of consumption.

** For estimates of the firm supply of electric power to the Angarsk Gaseous Diffusion Plant from various sources for each year of the period 1957-65, see Table 5, Appendix A.

*** For estimates of the amounts of electric power used each year for diffusion cascade pumping, see Table 4, Appendix A.

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B. Three Main Sources of Supply

During the first 2 years of operation -- that is, through August 1959 -- the Angarsk Gaseous Diffusion Plant received its power supply over two 220-kv lines from the Irkutsk GES, with 110-kv ties to the Irkutsk GES and to TETs 1 as backup. From mid-1958 to mid-1962 about 3 billion kwh a year were drawn by the diffusion plant from the Irkutsk GES. This amount of power constituted roughly three-fourths of the power produced by the GES. The peak load drawn from the GES is estimated to have reached 360 mw in August 1958 and to have continued at this level through mid-1962. After this date, supply from the Irkutsk GES to the diffusion plant declined as more power from the GES was consumed by the new Irkutsk Aluminum Plant. Power from the Bratsk GES made up the difference in the supply of the diffusion plant. It is estimated that by mid-1964 the diffusion plant no longer was drawing significant amounts of power from the Irkutsk GES.

In September 1959, TETs 10 began to supply power to the diffusion plant. By April 1962 the supply of power from this source amounted to 6.2 billion kwh. The peak load drawn by the diffusion plant from TETs 10 reached an estimated total of 750 mw by April 1962 and has remained at this level since that time.

In May 1962 the diffusion plant began to draw significant amounts of electric power from the Bratsk GES. It is estimated that the load drawn by the diffusion plant from the Bratsk GES reached 300 mw in December 1962 and 750 mw by mid-1963. At that time the diffusion plant also was drawing about 290 mw from the Irkutsk GES and 750 mw from TETs 10. In mid-1964 the diffusion plant was drawing close to 1,040 mw from the Bratsk GES and 750 mw from TETs 10. Consumption of electric power in 1964 is estimated to be at a rate of 14.9 billion kwh a year, 8.7 billion kwh of which are supplied by the Bratsk GES and 6.2 billion kwh by TETs 10.

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APPENDIX A

STATISTICAL TABLES

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Table 1

USSR: Estimated End-of-the-Year Capacity of Powerplants in Irkutskaya Oblast
1950-65

| | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 |
|--|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Powerplants in the Irkutsk Power System | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 28 | 28 | 28 | 28 | 28 | 28 |
| Irkutsk TETs 2 a/ | | | | | | | | | | | | | | | | |
| Angarsk TETs 1 | | | | | | | | | | | | | | | | |
| Irkutsk GES b/ | | | | | | | | | | | | | | | | |
| Angarsk TETs 10 | | | | | | | | | | | | | | | | |
| Usol'ye TETs 11 | | | | | | | | | | | | | | | | |
| Zima TETs 3 | | | | | | | | | | | | | | | | |
| Irkutsk IAZ TETs 5 c/ | | | | | | | | | | | | | | | | |
| Bratsk GES d/ | | | | | | | | | | | | | | | | |
| Angarsk Refinery TETs 9 | | | | | | | | | | | | | | | | |
| Bratsk TETs | | | | | | | | | | | | | | | | |
| Korshunovo TETs | | | | | | | | | | | | | | | | |
| Baykalsk Utulik TETs | | | | | | | | | | | | | | | | |
| Irkutsk Power System | 22 | 22 | 80 | 155 | 260 | 290 | 483 | 829 | 980 | 1,082 | 1,606 | 2,831 | 4,374 | 5,824 | 5,936 | 6,623 |
| Block powerplants e/ | 53 | 53 | 53 | 53 | 53 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| Other powerplants f/ | 85 | 85 | 87 | 102 | 127 | 134 | 151 | 155 | 164 | 172 | 188 | 223 | 240 | 240 | 248 | 251 |
| Total | 160 | 160 | 220 | 310 | 440 | 480 | 690 | 1,040 | 1,200 | 1,310 | 1,850 | 3,110 | 4,670 | 6,120 | 6,240 | 6,930 |

a. Teploelektrotsentral' (heating and powerplant).
b. Gidroelektricheskaya stantsiya (hydroelectric powerplant).
c. Irkutsk Aluminum Zavod (plant).

d. Figures for the Bratsk GES indicate installed generating capacity. Total capacity cannot be fully utilized until about 1967, when the water level of the Bratsk reservoir will reach the height planned.

e. Small industrial powerplants physically connected to, but not administratively a part of, the Irkutsk Power System.

f. Small powerplants that are not connected administratively or physically to the system and that serve diverse activities such as agriculture, mining, and timber camps.

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Table 2

USSR: Estimated Annual Production of Electric Power at Powerplants in Irkutskaya Oblast a/
1950-65

| | Million Kilowatt-Hours | | | | | | | | | | | | | | | |
|--|------------------------|------|------|------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|
| | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 |
| Powerplants in the Irkutsk Power System | 80 | 100 | 100 | 100 | 100 | 105 | 105 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Irkutsk TETs 2 b/ | | | | | | | | | | | | | | | | |
| Angarsk TETs 1 | | | 135 | 190 | 360 | 890 | 1,345 | 1,100 | 1,860 | 2,370 | 2,380 | 1,975 | 1,900 | 1,900 | 1,900 | 1,900 |
| Irkutsk GES c/ | | | | | | | | 800 | 2,800 | 3,500 | 3,500 | 3,900 | 3,600 | 4,000 | 4,100 | 4,100 |
| Angarsk TETs 10 | | | | | | | | | | 230 | 2,700 | 5,000 | 6,900 | 7,000 | 7,000 | 7,000 |
| Usol'ye TETs 11 | | | | | | | | | | | 300 | 400 | 450 | 600 | 700 | 900 |
| Zima TETs 3 | | | | | | | | | | | 20 | 60 | 75 | 100 | 100 | 100 |
| Irkutsk IAZ TETs 5 d/ | | | | | | | | | | | | 25 | 50 | 75 | 100 | 100 |
| Bratsk GES | | | | | | | | | | | | 80 | 2,880 | 7,900 | 11,000 | 12,000 |
| Angarsk Refinery TETs 9 | | | | | | | | | | | | | | 225 | 600 | 725 |
| Bratsk TETs | | | | | | | | | | | | | | | 50 | 200 |
| Korshunovo TETs | | | | | | | | | | | | | | | 50 | 100 |
| Baykalsk Utulik TETs | | | | | | | | | | | | | | | | 50 |
| Irkutsk Power System | 80 | 100 | 235 | 290 | 460 | 995 | 1,450 | 2,000 | 4,760 | 6,200 | 9,000 | 11,540 | 15,955 | 21,900 | 25,700 | 27,275 |
| Block powerplants e/ | 250 | 270 | 285 | 285 | 280 | 290 | 280 | 205 | 140 | 285 | 275 | 230 | 220 | 200 | 200 | 200 |
| Other powerplants f/ | 280 | 290 | 280 | 325 | 360 | 415 | 470 | 495 | 500 | 515 | 525 | 530 | 525 | 500 | 500 | 525 |
| Total | 610 | 660 | 800 | 900 | 1,100 | 1,700 | 2,200 | 2,700 | 5,400 | 7,000 | 9,800 | 12,300 | 16,700 | 22,600 | 26,400 | 28,000 |

a. For the methodology used in the derivation of figures, see Appendix B.

b. Teploelektrotsentral' (heating and powerplant).

c. Gidroelektricheskaya stantsiya (hydroelectric powerplant).

d. Irkutsk Aluminum Zavod (plant).

e. Small industrial powerplants physically connected to, but not administratively a part of, the Irkutsk Power System.

f. Small powerplants that are not connected administratively or physically to the system and that serve diverse activities such as agriculture, mining, and timber camps.

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Table 3

USSR: Estimated Annual Consumption of Electric Power Generated in Irkutskaya Oblast* 1950-65

| | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 |
|--|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|
| Total consumption a/ | 610 | 800 | 800 | 900 | 1,100 | 1,700 | 2,200 | 2,700 | 5,400 | 7,000 | 9,800 | 12,300 | 16,700 | 22,600 | 26,400 | 28,000 |
| Consumption, not including industry b/ | 240 | 250 | 310 | 350 | 430 | 580 | 790 | 930 | 1,300 | 1,740 | 2,340 | 2,970 | 3,960 | 4,690 | 6,440 | 7,000 |
| Exports c/ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 200 | 1,600 | 1,800 |
| Station use | 50 | 50 | 60 | 70 | 90 | 130 | 180 | 150 | 220 | 290 | 510 | 680 | 840 | 900 | 950 | 1,000 |
| Line loss | 30 | 30 | 40 | 50 | 60 | 100 | 120 | 160 | 340 | 450 | 630 | 790 | 1,100 | 1,500 | 1,630 | 1,720 |
| Construction | 30 | 40 | 50 | 60 | 80 | 110 | 140 | 160 | 200 | 260 | 280 | 300 | 300 | 260 | 260 | 260 |
| Transport | 40 | 40 | 50 | 50 | 60 | 60 | 140 | 220 | 280 | 440 | 590 | 820 | 1,200 | 1,370 | 1,480 | 1,640 |
| Urban economy | 70 | 70 | 80 | 90 | 100 | 120 | 140 | 160 | 170 | 190 | 210 | 240 | 270 | 300 | 340 | 380 |
| Rural economy | 20 | 20 | 30 | 30 | 40 | 60 | 70 | 80 | 90 | 110 | 120 | 140 | 150 | 160 | 180 | 200 |
| Consumption by total industry d/ | 370 | 410 | 490 | 550 | 670 | 1,120 | 1,410 | 1,770 | 4,100 | 5,260 | 7,460 | 9,330 | 12,740 | 17,910 | 19,960 | 21,000 |
| Consumption by industry not including Combine 16 and the Angarsk Gaseous Diffusion Plant | 370 | 410 | 420 | 470 | 500 | 590 | 640 | 680 | 790 | 830 | 900 | 1,060 | 1,640 | 2,490 | 3,570 | 4,540 |
| Coal | 70 | 70 | 80 | 90 | 90 | 110 | 120 | 120 | 120 | 100 | 100 | 120 | 120 | 130 | 140 | 140 |
| Petroleum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chemicals | 40 | 40 | 40 | 40 | 50 | 50 | 60 | 70 | 70 | 80 | 90 | 120 | 160 | 240 | 340 | 470 |
| Ferrous metals | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 50 |
| Nonferrous metals | 30 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 | 40 | 40 | 50 | 440 | 1,060 | 1,870 | 2,480 |
| Machine building and metalworking | 110 | 140 | 140 | 140 | 150 | 170 | 180 | 200 | 220 | 230 | 240 | 260 | 280 | 300 | 340 | 380 |
| Timber, woodworking, and paper | 30 | 30 | 30 | 40 | 40 | 50 | 60 | 60 | 70 | 70 | 80 | 80 | 90 | 100 | 110 | 140 |
| Construction materials | 10 | 10 | 10 | 20 | 20 | 20 | 30 | 30 | 30 | 120 | 140 | 140 | 160 | 170 | 180 | 180 |
| Light industry | 10 | 10 | 10 | 10 | 10 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 | 40 | 40 | 50 |
| Food industry | 20 | 20 | 20 | 30 | 30 | 40 | 40 | 40 | 50 | 50 | 50 | 60 | 70 | 80 | 80 | 90 |
| Other industry | 50 | 60 | 60 | 70 | 80 | 90 | 90 | 100 | 110 | 120 | 120 | 140 | 160 | 180 | 210 | 230 |
| Consumption by Combine 16 and the Angarsk Gaseous Diffusion Plant e/ | 0 | 0 | 70 | 80 | 170 | 530 | 770 | 1,090 | 3,310 | 4,430 | 6,560 | 8,270 | 11,100 | 15,420 | 16,390 | 16,460 |
| Consumption by conventional industry f/ | 370 | 410 | 490 | 550 | 590 | 680 | 730 | 830 | 1,000 | 1,150 | 1,240 | 1,460 | 2,140 | 3,090 | 4,270 | 5,340 |

* Footnotes follow on p. 16.

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Table 3

USSR: Estimated Annual Consumption of Electric Power Generated in Irkutskaya Oblast
1950-65
(Continued)

| | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 |
|--|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|--------|--------|--------|
| Consumption for production of nuclear materials g/ | 0 | 0 | 0 | 0 | 80 | 170 | 530 | 770 | 940 | 3,100 | 4,110 | 6,220 | 7,870 | 10,600 | 14,820 | 15,660 |
| Consumption at Combine 16 - Total h/ | 0 | 0 | 70 | 80 | 80 | 170 | 530 | 770 | 920 | 1,010 | 1,120 | 1,140 | 1,200 | 1,300 | 1,400 | 1,500 |
| For conventional industrial production | 0 | 0 | 70 | 80 | 90 | 90 | 90 | 90 | 150 | 210 | 320 | 340 | 400 | 500 | 600 | 700 |
| For nuclear materials production | 0 | 0 | 0 | 0 | 80 | 80 | 440 | 680 | 770 | 800 | 800 | 800 | 800 | 800 | 800 | 800 |
| Consumption at Angarsk Gaseous Diffusion Plant i/ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | 2,300 | 3,310 | 5,420 | 7,070 | 9,800 | 14,020 | 14,890 |

a. Total consumption equals production (from Table 2) because production and consumption occur simultaneously. To facilitate deriving consumption by industry as a residual, the small amounts of power exported in 1962 and later years have been treated as "consumption." For an explanation of the derivation of production of power in Irkutskaya Oblast, see Appendix B, Methodology.

b. The sum of estimates of exports and electric power consumed for purposes other than industrial production. For the derivation of estimates of consumption for nonindustrial purposes, see Appendix B, Methodology.

c. Exports are net because there are no imports.

d. Derived as a residual by subtracting consumption for all other purposes from total production. Hence consumption of power for production of nuclear materials is included.

e. Derived as a residual by subtracting consumption of electric power for all other industrial purposes from total consumption of electric power by industry.

f. Consumption for all industrial production except production of nuclear materials. Consumption for production of petroleum and chemical products at Combine 16 is included. For method of derivation, see Appendix B, Methodology.

g. Derived as a residual by subtracting consumption by conventional industry from consumption by total industry.

h. For derivation and allocation of consumption at Combine 16, see Appendix B, Methodology.

i. Derived as a residual in all years except 1957. For details, see Appendix B, Methodology.

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Table 4

USSR: Estimated Monthly Peak Load and Consumption of Electric Power for All Uses and for Cascade Pumping Only at the Angarsk Gaseous Diffusion Plant a/* 1957-65

| Month | 1957 | | | 1958 | | | 1959 | | | 1960 | | |
|----------------------------|-------------------|------------------------------|---|-------------------|------------------------------|---|-------------------|------------------------------|---|-------------------|------------------------------|---|
| | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) |
| January | | | | 135 | 90 | 4 | 360 | 250 | 10 | 540 | 370 | 15 |
| February | | | | 165 | 110 | 5 | 360 | 250 | 10 | 570 | 400 | 17 |
| March | | | | 195 | 140 | 6 | 360 | 250 | 10 | 600 | 420 | 18 |
| April | | | | 225 | 160 | 7 | 360 | 250 | 10 | 630 | 440 | 18 |
| May | | | | 255 | 180 | 8 | 360 | 250 | 10 | 660 | 460 | 19 |
| June | | | | 285 | 200 | 8 | 360 | 250 | 10 | 690 | 480 | 20 |
| Total, year ending 30 June | | | | | | | | | | | | |
| July | | | 14 | | | | 360 | 250 | 10 | 690 | 480 | 18 |
| August | | | 9 | 315 | 220 | 9 | 390 | 270 | 11 | 690 | 480 | 20 |
| September | 15 | 10 | 10 | 345 | 230 | 10 | 420 | 290 | 12 | 690 | 480 | 20 |
| October | 45 | 30 | 1 | 360 | 250 | 10 | 450 | 310 | 13 | 690 | 480 | 20 |
| November | 75 | 50 | 2 | 360 | 250 | 10 | 480 | 330 | 14 | 690 | 480 | 20 |
| December | 105 | 70 | 3 | 360 | 250 | 10 | 510 | 350 | 15 | 690 | 480 | 20 |
| Total, calendar year | | | 170 | | 2,300 | | | 3,300 | | | 5,400 | |

* Footnotes follow on p. 18.

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Table 4
 USSR: Estimated Monthly Peak Load and Consumption of Electric Power for All Uses
 and for Cascade Pumping Only at the Angarsk Gaseous Diffusion Plant a/
 1957-65
 (Continued)

| Month | 1961 | | | 1962 | | | 1963 | | | 1964 and 1965 | | |
|----------------------------|-------------------|------------------------------|---|-------------------|------------------------------|---|-------------------|------------------------------|---|-------------------|------------------------------|---|
| | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) | Peak Load b/ (mw) | Consumption c/ (Million kwh) | Power for Cascade Pumping d/ (Thousand mwd) |
| January | 690 | 480 | 20 | 1,050 | 730 | 30 | 1,390 | 960 | 40 | 1,790 | 1,240 | 52 |
| February | 720 | 500 | 21 | 1,080 | 750 | 31 | 1,440 | 1,000 | 42 | 1,790 | 1,240 | 52 |
| March | 750 | 520 | 22 | 1,110 | 770 | 32 | 1,490 | 1,030 | 43 | 1,790 | 1,240 | 52 |
| April | 780 | 540 | 22 | 1,110 | 770 | 32 | 1,590 | 1,100 | 46 | 1,790 | 1,240 | 52 |
| May | 810 | 560 | 23 | 1,130 | 780 | 32 | 1,690 | 1,170 | 49 | 1,790 | 1,240 | 52 |
| June | 840 | 580 | 24 | 1,160 | 800 | 33 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| Total, year ending 30 June | | | 252 | | | 352 | | | 491 | | | 604 |
| July | 870 | 600 | 25 | 1,190 | 820 | 34 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| August | 900 | 620 | 26 | 1,220 | 850 | 35 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| September | 930 | 640 | 27 | 1,250 | 870 | 36 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| October | 960 | 670 | 28 | 1,280 | 890 | 37 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| November | 990 | 690 | 29 | 1,310 | 910 | 38 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| December | 1,020 | 710 | 30 | 1,340 | 930 | 39 | 1,790 | 1,240 | 52 | 1,790 | 1,240 | 52 |
| Total, calendar year | | 7,100 | | | 2,800 | | | 14,000 | | | 14,900 | |

a. Figures for monthly load, consumption, and pumping power were derived from the estimates of annual consumption developed in Table 3 and are presented not as exact estimates but as general orders of magnitude. The sum of the monthly consumption figures does not always agree with the estimate of annual consumption from which the monthly figures were derived because of the approximate nature of the utilization factors employed.

b. Average load for month, in megawatts (mw).

c. Consumption of electric power for all uses, in millions of kilowatt-hours (kwh), at an assumed average load factor of about 95 percent. Because of rounding, data may differ from Table 3.

d. Monthly consumption (measured in million kilowatt-hours) converted to pumping power (measured in thousand megawatt-days -- mwd) on the basis of 1 megawatt-day equal to 24,000 kilowatt-hours.

Table 5

USSR: Estimated Firm Supply of Electric Power
to the Angarsk Gaseous Diffusion Plant a/*
1957-65

| | | 110-kilovolt Network | | | | 220-kilovolt Network | | 500-kilovolt Network | | Megawatts | |
|----------|--------|----------------------|-------------|-------------|------------|----------------------|------------|----------------------|-------|------------------------|------------------|
| | | TETs 1 | Irkutsk GES | Irkutsk GES | Bratsk GES | Bratsk GES | Bratsk GES | TETs 10 | Total | Less Largest Component | Total Firm Power |
| Mid 1957 | 100 b/ | 60 c/ | 100 | | | | | | 260 | 100 | 160 |
| End 1957 | 100 | 60 | 340 d/ | | | | | | 500 | 170 | 330 |
| Mid 1958 | 100 | 60 | 500 e/ | | | | | | 660 | 250 | 410 |
| End 1958 | 100 | 60 | 500 | | | | | | 660 | 250 | 410 |
| Mid 1959 | 100 | 60 | 500 | | | | | | 660 | 250 | 410 |
| End 1959 | 100 | 60 | 500 | | | | 90 f/ | | 750 | 250 | 500 |
| Mid 1960 | 100 | 60 | 500 | | | | | 360 | 1,020 | 250 | 770 |
| End 1960 | 100 | 60 | 500 | | | | | 495 | 1,155 | 250 | 905 |
| Mid 1961 | 100 | 60 | 500 | | | | | 495 | 1,155 | 250 | 905 |
| End 1961 | 100 | 60 | 500 | | | | | 765 | 1,425 | 250 | 1,175 |
| Mid 1962 | | | 500 | 200 g/ | 300 h/ | | | 900 | 1,900 | 300 | 1,600 |
| End 1962 | | | 500 | 200 | 600 i/ | | | 900 | 2,200 | 300 | 1,900 |
| Mid 1963 | | | 500 | 200 | 1,200 j/ | | | 900 | 2,800 | 900 | 1,900 |
| End 1963 | | | 500 | 200 | 1,200 | | | 900 | 2,800 | 900 | 1,900 |
| Mid 1964 | | | 500 | 200 | 1,800 k/ | | | 900 | 3,400 | 900 | 2,500 |
| End 1964 | | | 500 | 200 | 1,800 | | | 900 | 3,400 | 900 | 2,500 |
| Mid 1965 | | | 500 | 200 | 1,800 | | | 900 | 3,400 | 900 | 2,500 |
| End 1965 | | | 500 | 200 | 1,800 | | | 900 | 3,400 | 900 | 2,500 |

* Footnotes follow on p. 20.

Table 5

USSR: Estimated Firm Supply of Electric Power
to the Angarsk Gaseous Diffusion Plant a/
1957-65
(Continued)

- a. Firm supply is the amount of electric power that can be furnished even if the largest single supplier is out of commission.
- b. One 110-kilovolt (kv) line 5 kilometers (km) long.
- c. One 110-kv line 30 km long.
- d. Limited by transformer capacity.
- e. Two 220-kv lines 30 km long.
- f. Installed capacity less 10 percent line loss and station use.
- g. One 220-kv line.
- h. One 500-kv line operating at 220-kv.
- i. Two 500-kv lines operating at 220-kv.
- j. One 500-kv line and one 500-kv line operating at 220-kv.
- k. Two 500-kv lines.

APPENDIX B

METHODOLOGY

I. Production

A. Total in Irkutskaya Oblast

Data on production of electric power in Irkutskaya Oblast in the years 1950-58 are based on reported production in 1955 ^{1/}* and 1957 ^{2/} and on a reported index of production 1955-58 (1950 = 100). ^{3/} Estimates of production in Irkutskaya Oblast in 1951-54 were derived by subtracting estimates of annual production in all other oblasts of East Siberia from the reported total annual production in East Siberia. The estimates for other oblasts represented published data for some years and interpolations for other years. Production in Irkutskaya Oblast in 1959 was reported to be 2.5 times that in 1957 (probably excluding Angarsk TET's 10). ^{4/} Estimates of production in 1960-65 are the summation of estimated production at individual powerplants. The estimates of production at individual powerplants were based on estimated average installed capacity and estimated average hours of operation. Planned production in Irkutskaya Oblast in 1965 was set at 38 billion to 43 billion kwh in the original Seven Year Plan, ^{5/} but on the basis of estimated production at individual powerplants it appears probable that production will be only about 28 billion kwh.

The margin of error on estimates of total production during the years 1950-57 is approximately plus or minus 50 million kwh. The margin of error increases for subsequent years, as the estimates are based on (1) estimates of production at individual powerplants and (2) a residual of reported production in East Siberia in 1960-62. The possible margin of error increases from 200 million kwh during the years 1958-59 to 1,000 million kwh in 1965.

B. Individual Powerplants

Estimates of production of electric power at individual powerplants were based, unless otherwise indicated, on the estimated average installed capacity and the estimated average hours of operation.

* For serially numbered source references, see Appendix C.

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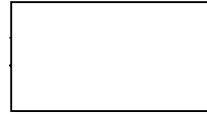
Estimates of production at Angarsk TETs 1 were derived by subtracting known or estimated production at other powerplants from the total annual production in Irkutskaya Oblast in 1952-58. During 1959 and 1960, growth in demand for power in the oblast, especially at the gaseous diffusion plant, necessitated increased utilization of powerplant capacity. Production at TETs 1 in 1959 was "more than twice" the amount produced in 1957 6/ and probably continued at approximately the same level in 1960. Thereafter an increasing share of the demand was satisfied by efficient new powerplants, especially TETs 10 and the Bratsk GES, and utilization of capacity at TETs 1 returned to a lower level. It is estimated that production in 1961 was according to plan -- 1,975 million kwh 7/ -- and that production in subsequent years has been at a level slightly below the 1961 plan.

Estimates of production of electric power at the Irkutsk GES were based on Soviet statements that cumulative production reached 1,000 million kwh by 5 February 1958, 8/ 1,360 million kwh by 15 April 1958, 9/ 2,000 million kwh by 1 July 1958, 10/ over 14,000 million kwh by 24 December 1961, 11/ and 22,000 million kwh by the end of 1963. 12/ The plan for 1961 was 3,600 million kwh, 13/ but this was fulfilled on 28 November 1961, 14/ and probably 300 million additional kwh were produced in December. Production in 1964 and 1965 is assumed to be at the designed level of 4,100 million kwh annually. 15/

Estimates of production of electric power at Angarsk TETs 10 were based on a previous study of installation of generating equipment at this plant. 16/ The assumption was made that in 1959-60 when there was a power shortage, equipment at TETs 10 was operated at an average of 8,000 hours a year and that utilization was reduced to about 7,000 hours after the Bratsk GES came into operation. Observers in 1962-63 reported all four smokestacks smoking heavily; so it is unlikely that the plant was operating at much less than the 80 percent plant factor indicated by 7,000 hours.

The Bratsk GES was planned to produce 80 million kwh in 1961, 17/ and had produced a cumulative total of 2,960 million kwh by the end of 1962 18/ and about 10,860 million kwh by the end of 1963. 19/ It is expected to produce an annual total of 11 billion to 12 billion kwh in 1964 and 1965. 20/

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C. Groups of Powerplants

Production of electric power in the Irkutsk Power System was calculated as a residual by subtracting production at plants outside the system from total annual production in the Irkutskaya Oblast in 1950-58. In 1959, production in the system, excluding Angarsk TETs 10, was 25 percent greater than in 1958. 21/ TETs 10 was not included in the planning for the Irkutsk Power System in 1961, 22/ and it is likely that this powerplant, which serves only the Angarsk Gaseous Diffusion Plant, is not included in reporting on the Irkutsk Power System for other years. Production of electric power in the Irkutsk Power System in 1960, 1962, and later years was estimated by adding together estimates of production at individual powerplants in the system. The estimate for 1961 represents planned production 23/ by plants of the system plus estimated production at TETs 10.

Block stations in the Irkutsk Power System include factory powerplants physically connected to the system but not included in it for accounting purposes. The powerplants are at the Kuybyshev Machine Building Plant, at Aircraft Plant 39, at Cheremkovo, at Usol'ye, and at Makaryevo. Production has been estimated on the basis of capacity and a reasonable utilization factor.

The estimated production of electric power in small isolated powerplants is based on the estimated consumption needs of areas and towns located in Irkutskaya Oblast but not connected to the Irkutsk Power System.

II. Consumption

Consumption of electric power by the nuclear materials industry in Irkutskaya Oblast was derived as a residual by subtracting consumption of power by all other users from the total production of power in the Oblast. Subtraction from production was appropriate because production and consumption of power occur simultaneously; therefore, information on total production can be equated to total consumption, including exports. Estimates of consumption of electric power by sector of the economy were derived in a variety of ways, depending on available information.

A. Consumption by Consumers Not Connected with Production of Nuclear Materials

Consumption of electric power for construction of the Irkutsk and Bratsk Hydroelectric Powerplants -- which has been reported 24/ --



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makes up most of the consumption by construction enterprises. Estimates of additional consumption by construction enterprises were based on annual expenditures for construction and national averages of consumption of electric power per ruble of construction-installation work.

Estimates of consumption of electric power by the transport sector, principally by the electrified railroads, have been calculated from gross ton-kilometers hauled and consumption of electric power per ton-kilometer. Both of these magnitudes have been reported.

Estimates of consumption of electric power for urban living uses were based on population of towns and consumption per person. Consumption per person was based on national norms and averages for towns of appropriate sizes.

Estimated consumption of electric power by agriculture is based on the reported capacity of motors used in agriculture in Irkutskaya Oblast in 1950-57. 25/ It was assumed that in these years consumption was in the same relation to capacity in Irkutskaya Oblast as in the RSFSR. Planned consumption of electric power by agriculture in 1965 is 202 billion kwh. 26/ Consumption in other years was estimated by interpolation.

Losses of electric power in transmission networks were calculated at a reported average of approximately 7 percent. 27/ Electric power used by powerplants was calculated at 8 percent for thermal electric powerplants and 0.3 percent for hydroelectric powerplants -- average figures for these kinds of powerplants.

Estimates of electric power sent out as exports during 1962-63 represent a part of the consumption of the Tayshet-Klyukvennaya sector of the Trans-Siberian Railroad in Krasnoyarskiy Kray. When the Bratsk-Tayshet 500-kv transmission line was completed at the end of 1963, it furnished additional power over the already existing 500-kv line from Tayshet to Kamala, increasing the transmission of power to Krasnoyarskiy Kray by seven to eight times. 28/ Both of these lines operated at 220 kv in 1964 and probably will continue to do so in 1965. Starting in 1965, an estimated 100 million kwh will be transmitted to the Buryatskaya ASSR primarily for electrification of the Trans-Siberian Railroad from Slyudyanka to Ulan-Ude.

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Estimates of the total annual consumption of electric power by industry, including consumption by the nuclear materials industry, were derived by subtracting the estimated amounts of power allocated to all other uses from the total production of power in Irkutskaya Oblast. Estimates of consumption of electric power by various branches of industry not connected with production of nuclear materials were derived by multiplying the reported output of branches of industry by appropriate factors for consumption of electric power per unit of output -- for example, consumption of electric power per ton of coal, cement, or other product produced. In some cases, output by branch of industry was derived on a plant-by-plant basis. Estimates of the output of petroleum and chemical products derived in this fashion did not include output of such products at Combine 16. The category "other" includes some industrial production, such as mining and processing of mica that is not included elsewhere. A variety of other types of information, including fragmentary data on planned or actual consumption, roof cover, and labor force, also was used.

Summation of consumption by all sectors of the economy, including consumption by conventional industries, did not account for all of the electric power produced in the oblast. Analysis of the geographic distribution of consumption of power in the oblast indicated that the residual was concentrated in the vicinity of Angarsk and that it probably represents the amount of power consumed by the Angarsk Gaseous Diffusion Plant and Angarsk Synthetic Fuels Combine 16.

B. Consumption by the Angarsk Synthetic Fuels Combine 16

Consumption of electric power by Angarsk Synthetic Fuels Combine 16 consists of power allocated to production of petroleum and chemical products and of power probably allocated to production of nuclear materials. Through 1956 -- that is, prior to the operation of the Angarsk Gaseous Diffusion Plant -- the total consumption of electric power at Combine 16 could be calculated as a residual by subtracting the sum of estimates of consumption by other users of power from the total production of power in Irkutskaya Oblast. This residual consumption of electric power was divided into consumption for conventional industrial production and consumption for production of nuclear materials in the following manner.

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Consumption of electric power by industry in the USSR as a whole during the years 1951 through 1960 grew at a rate only slightly more rapid than that associated with growth in the gross value of output of industry. Consequently, it was assumed that consumption of electric power for conventional industrial production in Irkutskaya Oblast grew at approximately the same rate as conventional industrial production. It was assumed further that in Irkutskaya Oblast the index of industrial production did not include any allowance for output of the nuclear materials industry. (This assumption appeared to be reasonable, as it is doubtful that such production would be subordinated to the Irkutsk Sovnarkhoz.) On the basis of these assumptions, an index of consumption of electric power by conventional industry (not including nuclear materials production) was derived from the officially published index of industrial production in Irkutskaya Oblast for the years 1950-60. 29/ The index of consumption of electric power by conventional industry was then converted to consumption measured in kilowatt-hours on the basis of an estimated consumption of 370 million kwh in 1950. (This estimate of consumption in the base year 1950 was derived from a regional power balance for that year.) The estimates of consumption by conventional industry thus obtained were reasonable for 1954-60. In 1951 and 1952 the figures thus derived were slightly larger, and in 1953 slightly smaller, than the previously derived estimates of total consumption by industry. The discrepancies were surprisingly small, probably resulting from inaccuracies in compilation of the indexes and estimates involved, and the estimates derived for total consumption by industry were selected for use as "consumption by conventional industry" in these three years. By subtracting from the estimates of total consumption by conventional industry the estimates previously derived for annual consumption by conventional industrial consumers other than Combine 16 (see Table 3*), estimates of annual consumption of electric power at Combine 16 for conventional industrial purposes were obtained for the years 1950-60. The figure derived from the index of industrial production for consumption by conventional industry in 1955 -- 650 million kwh -- implied an improbable drop in consumption of power for production of petroleum and chemical products at Combine 16 in that year. Therefore, the figure was adjusted upward to 680 million kwh to hold the estimate of consumption for conventional industrial production at Combine 16 at the level of the previous year. (In the years 1954-56 the difference between the estimates of consumption of power for conventional industrial production at Combine 16 and the estimates of

* Appendix A, p. 15, above.

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total consumption of electric power at Combine 16 probably was the consumption of electric power for production of nuclear materials.) Consumption by conventional industry in the years 1961-65 was estimated by adding consumption for such production at Combine 16 to consumption by industry not including Combine 16 or the Angarsk Gaseous Diffusion Plant (see Table 3).

Total consumption at Combine 16 in the years 1957 and following could not be derived as a residual by subtracting from total production the sum of estimates of consumption by other consumers not connected with the nuclear materials industry. The residual thus obtained (1,090 million kwh in 1957) also included the rapidly growing consumption of power at the new Angarsk Gaseous Diffusion Plant. On the basis of assumptions concerning reasonable development of the monthly load at the diffusion plant as it was phased into operation, and an assumed 95 percent load factor, it was estimated that the diffusion plant consumed a total of 170 million kwh during the last 4 months of 1957 (see Table 4*). This left a residual of 920 million kwh as total consumption of power at Combine 16 in 1957. Application of the same technique used to allocate consumption of electric power at Combine 16 in the years 1954-56, which became possible once consumption at the Angarsk Gaseous Diffusion Plant was eliminated, indicated that in 1957 at Combine 16 approximately 150 million kwh were used for conventional production and 770 million kwh for production of nuclear materials.

Application of the same technique for the years 1958-60 resulted in estimates of consumption of power at Combine 16 for conventional industrial production and a residual that represented total annual consumption of electric power for production of nuclear materials. This residual was allocated on the basis of an assumed consumption of about 800 million kwh per year for production of nuclear materials at Combine 16. This assumption was based on the absence of any evidence, even of an indirect nature, that the consumption of electric power for production of nuclear materials at Combine 16 has increased since 1957. The lack of growth in such consumption at Combine 16 after 1957 seems reasonable in view of the rapid expansion known to have occurred after that date at the Angarsk Gaseous Diffusion Plant.

Although consumption of electric power for production of nuclear materials at Combine 16 probably continued to be at about the same annual level in the years after 1960, consumption of power

* Appendix A, p. 17, above.

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for production of petroleum and chemical products probably continued to increase. The estimate of about 340 million kwh consumed for conventional industrial production in 1960 was rounded upward arbitrarily to 400 million kwh in 1961. Planned investment for installation work in 1961 ^{30/} indicated that consumption of power would increase by about 300 million kwh, probably over the next 2 to 3 years. On this basis it was estimated that consumption for conventional industrial production would increase at a rate of about 100 million kwh annually after 1961.

C. Consumption by the Angarsk Gaseous Diffusion Plant

Consumption of electric power by the Angarsk Gaseous Diffusion Plant in 1957 was estimated on the basis of reasonable assumptions concerning the development of the monthly load drawn by the plant as it was phased into operation. The estimates of consumption in subsequent years were derived as a residual by subtracting annual consumption by all other users from total annual production in Irkutskaya Oblast. These estimates are shown in Table 3 as they were derived, but the number of digits carried should not be regarded as an indication of the degree of accuracy ascribed to them. The possible error in the estimated amounts of electric power consumed by the diffusion plant may be as much as 15 percent. This margin of error is derived from possible errors in estimates of production, consumption by Combine 16, and consumption by other users.

APPENDIX C

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