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COMPARISON OF POWERPLANT TECHNOLOGY AND COSTS IN THE USSR AND THE UNITED STATES

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FOREWORD

Technological advances in the electric power industry are instituted almost exclusively to reduce costs of fuel, capital, and labor. Emphasis on technological improvement and on reducing costs associated with a particular factor depends on the relative importance of that factor in the total cost of producing electric power.

This report discusses the economic gains resulting from technological advances in the electric power industries of the USSR, of the United States, and, to a lesser extent, of some Western European countries. Focusing on technological developments that make a significant difference in factor inputs, this report is concerned primarily with the gains being achieved through improved technology in thermal electric powerplants, which account for more than 80 percent of total electric power generation in both the USSR and the United States.

Soviet cost data have been presented in rubles and US cost data in dollars. Because of the variation in ruble-dollar ratios implicit in data pertaining to various aspects of the electric power industry, no conversion to a common currency was made. The official rate of exchange of 0.90 ruble to US $1 does not accurately reflect the relationship existing between various costs in the electric power industries of the USSR and the United States. Moreover, no monetary conversion was necessary, as all international comparisons have been based on internal comparisons of other factors, such as efficiency of fuel consumption, numbers of production personnel per megawatt of capacity, internal savings achieved by economies of scale, and internal differences in costs of hydroelectric and thermal capacity.

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COMPARISON OF POWERPLANT TECHNOLOGY AND COSTS IN THE USSR AND THE UNITED STATES

Summary and Conclusions

The Soviet electric power industry has achieved substantial gains in efficiency in utilization of capital, fuel, and labor during the past decade. Since 1958 the investment required per kilowatt of new generating capacity has been reduced by about one-third. Operating efficiency has also increased in thermal electric powerplants, as the heat rate (that is, the expenditure of fuel required to produce one kilowatt-hour -- kwh -- of electricity) declined at an average annual rate of 2.2 percent from 1955 through 1963. The number of production personnel per megawatt of capacity at thermal powerplants declined at an average annual rate of 3.9 percent from 1958 through 1962. Nevertheless, the Soviet electric power industry still lags behind that of the United States in effective utilization of these factors.

The USSR uses about 15 percent more fuel per kilowatt-hour produced in thermal powerplants than does the United States, and it employs more than 10 times the number of production personnel per megawatt of installed capacity. Estimated investment in generating capacity installed in the Soviet electric power industry during 1959-65 exceeds planned costs by at least 10 percent. Soviet data, however, indicate that by increasing the average size of new generating units in thermal powerplants to the average size being installed in US thermal powerplants in 1965, the average cost per kilowatt of new capacity in Soviet thermal powerplants could be reduced by about 27 percent. Hydroelectric capacity is more expensive than capacity in thermal powerplants in both the USSR and the United States. The disparity between the costs of hydroelectric and thermal capacity in the USSR, however, is only about 40 percent as great as in the United States.

The disparities in the effectiveness of utilization of fuel, capital, and labor directly reflect the relative technological levels attained in the electric power industries of the two countries. Fuel costs in 1962 represented about 50 percent of the total cost of power produced in regional thermal powerplants in the USSR but only 29 percent of the total cost of power produced in thermal powerplants in the United States. Labor costs accounted for 31 percent of total cost in the United States, compared with only 14 percent in the USSR. Consequently, it is not surprising that the Soviet efforts at technological improvement stress fuel economy, whereas in the United States, technological improvement aimed at saving labor is deemed more significant. Amortization charges in the USSR represent about 25 percent of total costs, compared with 21 percent in the United States, and both countries show an appropriate interest in achieving economy in capital inputs.

The gap between the USSR and the United States in efficiency of fuel consumption probably will narrow in future years. Projection of present rates of decrease in the heat rates of the two countries would mean that the average heat rate in the USSR would not equal that of the United States before about 15 years. The rate of improvement in the Soviet industry undoubtedly will decline, however, as technical gains become harder to achieve. Because of the Soviet policy of standardization of equipment design, which sacrifices opportunity for rapid incorporation of technical advances in the interest of more immediate gains from reduced construction times and costs, it may be longer than 15 years before the Soviet heat rate equals that of the United States.

Gains in thermal efficiency are being accomplished in the USSR by employing larger boiler sizes that operate at higher temperatures and pressures. Until recently the standard equipment installed in large regional thermal powerplants in the USSR consisted of units of 150-megawatt (mw) or 200-mw capacity that operate at 1,850 pounds per square inch (psi) and 1,050° Fahrenheit (F). Soviet power engineers, however, are now installing a few newly designed supercritical* 300-mw units intended to operate at 3,400 psi and 1,050° F. Installation by the end of 1965 of thirteen 300-mw units, instead of approximately the same capacity in 200-mw units, is supposed to result in a planned economy of 33 million rubles in investment and subsequent annual savings of 9 million rubles in operating costs. The 300-mw units went into serial production, however, without sufficient operation of the prototype to eliminate difficulties, and apparently thus far none are operating at either design or supercritical levels. If they cannot be operated at design level, much if not all of the planned savings may be lost. Experimental work is also being done in the USSR on even larger units of 500-mw and 800-mw capacity.

Further economies in fuel consumption are being achieved by enlarging power distribution networks to take advantage of diversity in loads, thus achieving more constant demand and permitting a higher rate of utilization of the larger, most efficient generating units. Small power systems have, in the past, contributed to the lag in Soviet development of larger units.

The Soviet electric power industry is very slowly reducing the number of employees per unit of capacity by increasing the size of generating units and of powerplant capacities and by introduction of automation. Soviet powerplants not only lag behind those of the United States and Western Europe in extent of automation but are falling farther behind as a result of the rapid rate of Western advance in this field. The USSR apparently is not planning an extensive program to overcome this lag completely, because Soviet planning data for future large generating units call for approximately twice the number of operating personnel per unit of capacity that is anticipated in plants scheduled for construction in the United States.

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* See the first footnote on p. 5, below.

I. <u>Technological Efforts to Economize in the Use of Fuel in Soviet Thermal Electric Powerplants</u>

A. <u>Incentive</u>

Expenditures for fuel constitute the largest item of expense -- currently about 50 percent -- in the cost of electric power produced in regional thermal powerplants in the USSR, 1/* whereas they amount to only about 29 percent in the United States. 2/ Increased use of oil and gas and location of powerplants near sources of cheap coal supply have tended to reduce the cost of fuel to powerplants. The cost of fuel, however, is largely governed by factors outside the control of the power industry. Reductions in the expenditure for fuel have been achieved mainly through reduction of the heat rate. National heat rates offer perhaps the best gauge of the extent of technological advances in a country's power industry because they reflect the weighted averages of both efficient and inefficient generating units that contribute to the total national production of electric power.

In 1963 the USSR occupied fourth place among leading power producers in terms of fuel consumption per kilowatt-hour of electricity produced. The United States has the lowest rate of fuel consumption. Second place is held by France and third place by West Germany, as is shown in Table 1.

The average heat rate in the USSR, which was 24 percent greater than the average rate in the United States in 1955, was still 16 percent greater in 1963. Projection of the rates of decrease from 1955 to 1963 indicates that the average heat rate in the USSR will not equal that of the United States before about 15 years (see Figure 1). In fact, however, it may be even longer before the average Soviet heat rate overtakes that of the United States. The rate of decrease in the heat rate in the USSR is likely to slow down more than in the United States as a result of the Soviet practice of standardizing designs with consequent loss of opportunity to improve efficiency. In the United States, each generating unit is built essentially as a custom design and incorporates the latest technology almost as soon as it is developed.

There is considerable economic incentive for technological advancement in fuel saving. The average cost of fuel burned in powerplants in the USSR in 1960 was 39 kopecks per million British thermal units (btu), and is believed not to have changed significantly since that time. 3/** It is estimated that the net production of Soviet

* For serially numbered source references, see the Appendix.
** The average cost per million btu in the United States is about $0.26. 4/ The average cost of fuel in the United States, as in the USSR, has remained relatively static over the past five years.

regional thermal powerplants in 1963 was approximately 265 billion kwh. If thermal efficiency in these plants had been equal to the efficiency in US plants in that year, there would have been a saving of roughly 174 million rubles (about 14 percent of the total cost of fuel used) as a result of the reduction in fuel consumed.

Table 1

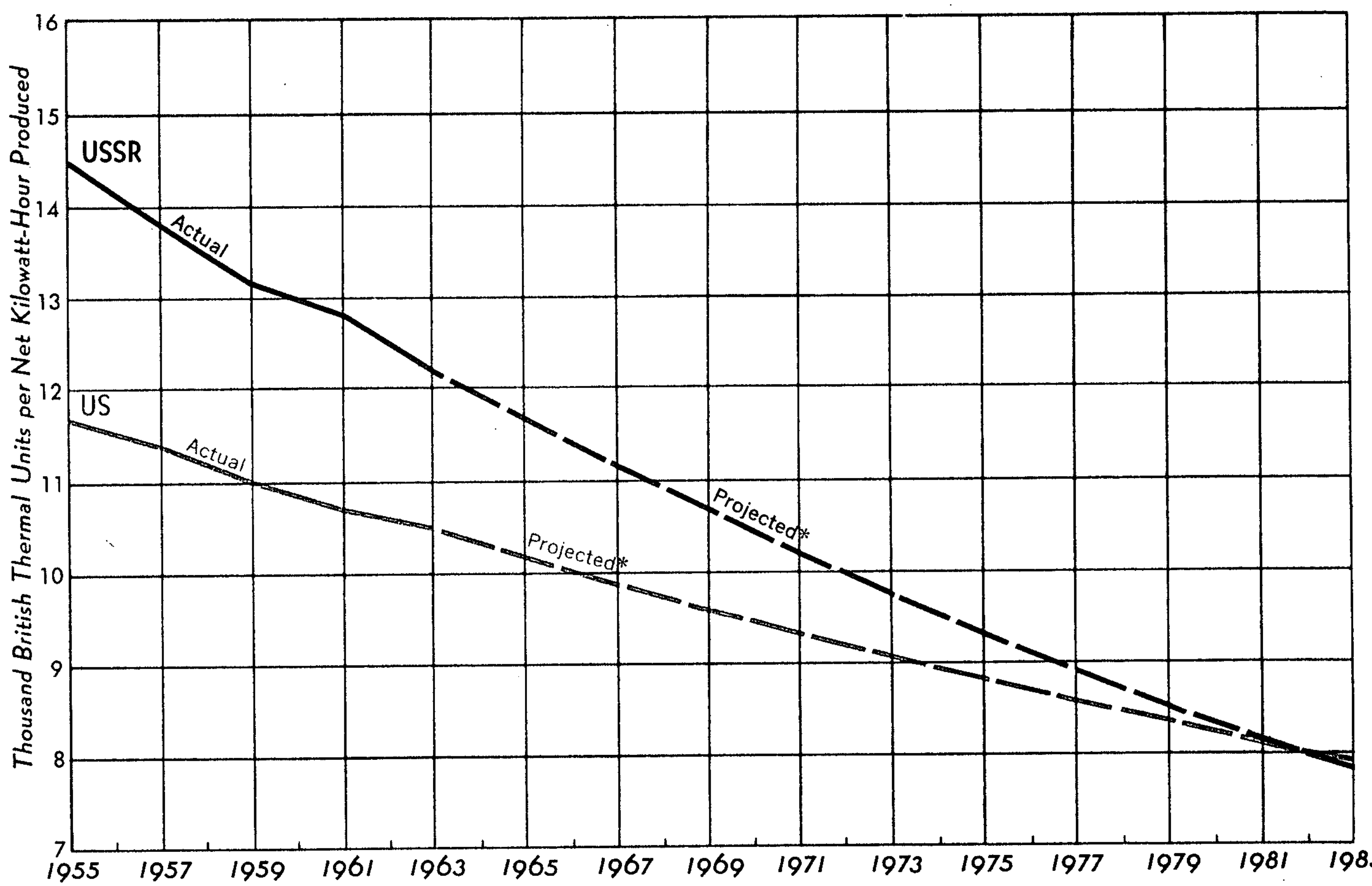
Average Heat Rates in Thermal Electric Powerplants in Public Utility Systems of Selected Countries a/
Selected Years, 1955-63

Year	United States b/	France c/	West Germany c/	USSR d/	United Kingdom c/
	British Thermal Units per Kilowatt-Hour Produced				
1955	11,700	16,500	14,600	14,500	14,100
1958	11,100	13,200	13,300	13,500	13,100
1960	10,800	11,900	12,400	13,000	12,800
1962	10,600	11,300	11,800	12,400	12,400
1963	10,500	11,100 e/	11,600	12,200	12,400
	Average Annual Rate of Decrease from 1955 Through 1963 (Percent) f/				
	1.4	4.8	2.9	2.2	1.6

a. Data have been rounded to the nearest 100 British thermal units per net kilowatt-hour produced.
b. 5/
c. Unless otherwise indicated, data are from source 6/. Data for France have been adjusted from a gross basis to a net basis by a factor of 7 percent.
d. 7/
e. Estimated.
f. Based on unrounded data.

Figure 1

USSR AND US
HEAT RATES IN THE ELECTRIC POWER INDUSTRY
1955-83



*Projected on the basis of the average annual rate of decrease during 1956-63.

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savings in capital stem from use of the "block" design principle, which unites into one unit a boiler, turbogenerator, and transformer. (Older designs called for spare boilers, which required expensive cross-connections.) The simplified block design saves on the cost of components and reduces the volume of buildings needed to enclose the equipment but increases possible losses from malfunction of the equipment. Practically all thermal powerplants built in the United States for more than a decade have incorporated block designs. The USSR has used block designs only in the 1960's and has just lately begun to construct TETs on block principles. The USSR lagged behind the United States in block design primarily because the USSR had not developed boilers with the necessary reliability.

Additional savings in capital are being attempted in the USSR: by construction of open-air powerplants, in which generating equipment is installed without a building enclosure; by increased utilization of oil and natural gas as fuel, thus reducing the problems of storage and the labor force and eliminating the conveying and crushing equipment required for coal-fired plants; and by streamlined construction techniques employing prefabricated parts and rigid schedules for delivery of materials. Open-air powerplants have been constructed in the USSR only since 1960, principally in the Caucasus and Central Asian regions, whereas such plants have long been common in the United States with its milder climate, which is more suitable for open-air construction. While the USSR is utilizing liquid and gaseous fuels in increasing amounts, less than one-fourth of its total power generation is based on these fuels, compared with more than one-third in the United States. Although Soviet construction techniques are improving, construction schedules are rarely fulfilled, and generating units seldom go into operation in less than three years from the start of powerplant construction. In the United States the first generating units often are placed in operation about two years after the beginning of powerplant construction. The additional construction time naturally adds to Soviet capital costs.

Soviet hydroelectric powerplants have the largest generating units, the largest total capacities, and the cheapest cost per kilowatt of capacity in the world. Substantial reductions in the capital costs of hydroelectric capacity in the USSR have been brought about largely by careful selection of favorable natural building sites. Reductions in the amount of earthworks and concrete required are responsible for most of the cost reduction. These reductions are evident in the comparison below of the Kuybyshev Hydroelectric Powerplant, which was put into operation in 1956, and the Bratsk Hydroelectric Powerplant, which was put into initial operation in 1961.

	Capacity (Megawatts)	Cost of Capacity (Rubles per Kilowatt)	Volume of Concrete (Million Cubic Meters)	Volume of Earthwork (Million Cubic Meters)
Kuybyshev	2,300	510	6.9	143
Bratsk	4,500 a/	140	4.9	42

a. The installed capacity of the Bratsk Hydroelectric Powerplant has reached 3,600 mw. The remaining generating units are scheduled for installation during the next two years.

C. Comparative Cost of Adding New Capacity

The USSR is achieving substantial reductions in the average cost per kilowatt of new electric generating capacity installed, although planned reductions in such costs are not being fully attained. The planned average cost per kilowatt of generating capacity installed during 1959-65 was 159 rubles, a reduction of 37 percent below the average of 252 rubles achieved during 1952-58. It is estimated that the average cost of capacity actually installed during the current plan period will be more than 170 rubles per kilowatt, a reduction of approximately 32 percent below the level of the previous period. The plan called for the addition of 58,000 to 60,000 mw during 1959-65, with an investment of 9.40 billion rubles. It appears that the goal for addition to capacity will be fulfilled. New capacity added during the period will total an estimated 60,300 mw, of which approximately 49,200 mw will be thermal powerplant capacity and about 11,100 mw will be hydroelectric capacity. It is estimated, however, that total investment will be at least 10.40 billion rubles* -- 10.6 percent in excess of plan (see Table 2). It seems likely that most of the overexpenditures can be attributed to delays in construction projects, caused by late delivery of materials and equipment, and to underestimation of the time required to introduce and perfect new models of generating units.

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* The actual cost of construction in the electric power industry during 1964-65 reportedly will be 1.3 billion rubles more than planned, 19/ of which approximately 1 billion rubles would be allocated for generating capacity and the remainder for transmission lines and heating networks. Recent reporting that the actual cost of many projects has been in excess of plan suggests a continuing problem. The cost of construction of electric powerplants during 1959-60 reportedly was approximately at the planned level. 20/ If overexpenditures during the entire period 1961-65 were at the rate indicated for the last two years, the total overexpenditure during 1959-65 could be as high as 2 billion rubles rather than the 1 billion shown above.

Table 2

Investment in Generating Capacity Installed in the USSR During 1959-65 a/

	Capacity Installed (Megawatts)		Investment (Billion Rubles)		Average Cost per Kilowatt of Capacity (Rubles)	
	Planned	Estimated	Planned	Estimated	Planned	Estimated
Thermal electric capacity	47,000 to 50,000	49,200	7.37	8.19 b/	152	166
Hydroelectric capacity	10,000 to 11,000	11,100	2.03	2.21 b/	193	199
Average investment c/					159	172
Total	58,000 to 60,000	60,300	9.40	10.40 b/		

a. Planned figures are as officially given except for the average cost per kilowatt of capacity, which is calculated on the basis of the midpoint of planned capacity.
b. Assuming that the overexpenditure should be apportioned according to the shares of thermal and hydroelectric capacity in the total new capacity added (see footnote c).
c. Thermal capacity makes up about 82 percent and hydroelectric capacity makes up about 18 percent of total capacity.

Soviet investment in thermal powerplants is less effective than such investment in the United States, where greater economies of scale are realized. The Soviet ruble buys slightly less capacity in thermal powerplants than does the US dollar, primarily because generating units of larger sizes are installed in US plants. The average cost per kilowatt of capacity added during 1959-65 is as follows:

	USSR a/ (Rubles)	United States (US $)
Thermal electric powerplants	137	126
Hydroelectric powerplants	199	290

a. The estimated average cost per kilowatt of capacity in the USSR during 1959-65 is based on Table 2. The figure of 166 rubles per kilowatt for thermal powerplants was adjusted to 137 rubles to eliminate the cost of items not found in US costs -- the share of TETs-type powerplants, which cost about 16 percent more than condensing-type plants, 21/ and the cost of housing and communal facilities, which make up about 12 percent of total costs of thermal powerplants. 22/

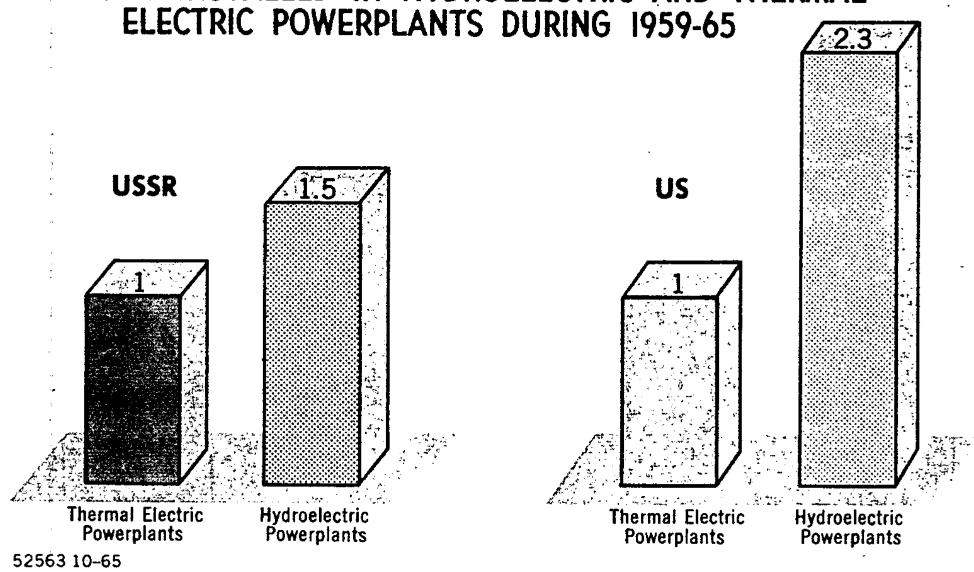
In the United States the average unit size installed has increased from 151 mw during 1959 to 221 mw during 1963 23/ and to an estimated 290 mw during 1965. By comparison, units scheduled for installation in the USSR during 1965 will average nearly 90 mw each. 24/ Soviet data indicate that a 200-mw increase in the average size of generating units would reduce current Soviet investment costs per kilowatt by about 27 percent. 25/

The advantage enjoyed by the USSR over the United States when investing in hydroelectric capacity, on the other hand, can be demonstrated by a comparison of the relative costs of hydroelectric capacity and thermal capacity in the two countries. As indicated in the above tabulation, investment in hydroelectric capacity during 1959-65 averaged 199 rubles per kilowatt in the USSR and $290 per kilowatt in the United States. Within the USSR, then, hydroelectric capacity costs about 1.5 times as much per kilowatt as thermal powerplant capacity, whereas in the United States, hydroelectric capacity costs 2.3 times as much per kilowatt as thermal powerplant capacity (see Figure 2). These ratios show that in the United States the cost of hydroelectric capacity in relation to thermal capacity is more than 1.5 times the same cost relationship in the USSR. Much of the difference in the ratios probably is accounted for by the availability in the USSR of choice natural hydroelectric sites which have no counterpart in the United States.

USSR AND US

Figure 2

RATIOS OF AVERAGE COSTS PER KILOWATT OF GENERATING CAPACITY INSTALLED IN HYDROELECTRIC AND THERMAL ELECTRIC POWERPLANTS DURING 1959-65



III. Technological Efforts to Economize in the Use of Labor

A. Incentive

The average annual wage in the Soviet electric power industry is roughly 1,300 rubles* and $6,300 in the US electric power industry. However, the number of production personnel employed per unit of capacity in Soviet thermal powerplants is more than 10 times the number employed in the United States. The total cost structure in the Soviet electric power industry is such that labor costs represent only about 14 percent of the total cost of power produced in thermal powerplants, compared with 31 percent in the United States. 26/ Nevertheless, there are significant potential gains from increasing labor productivity.

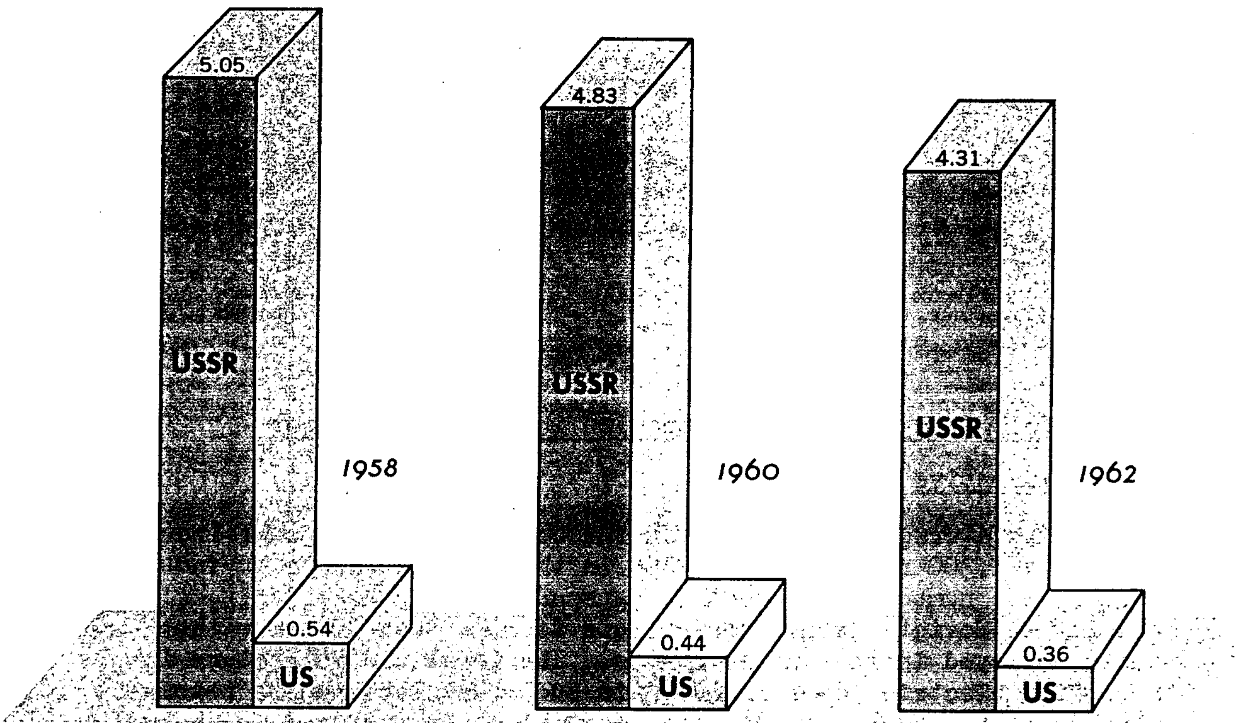
The relatively low percentage of total cost represented by labor costs may account for the fact that the Soviet industry apparently assigns less priority to increasing labor productivity through technological improvement than does the US industry. During 1958-62 the number of personnel per megawatt of capacity in thermal powerplants in the USSR decreased from 5.05 to 4.31. In the United States during the same period, there was an even larger percentage reduction, with

* The estimated average annual wage in 1962 per worker in regional thermal powerplants only.

the number of personnel per megawatt of capacity declining from 0.54 to 0.36.* 27/ Thus the gap appears to be widening steadily (see Figure 3). The improvement in labor productivity that is occurring in the USSR is being accomplished through increased automation of powerplants and economies of scale resulting from operation of larger generating units and of powerplants with larger capacities.

Figure 3

USSR AND US
NUMBER OF PRODUCTION PERSONNEL PER MEGAWATT OF CAPACITY IN THERMAL ELECTRIC POWERPLANTS, 1958, 1960, AND 1962



B. Automation

Although some degree of automation has been in evidence in the USSR for decades, extensive application of this technology is still in its infancy. The degree of automation in large hydroelectric powerplants is probably greater than in any other Soviet industry and is considered to be on a par with achievements in the United States. As early

* Comparable data for hydroelectric powerplants are not available, but it is likely that Soviet requirements for labor per unit of capacity are roughly the same as in the United States.

as 1959, one-third of the hydroelectric generating capacity in the USSR was remotely controlled. 28/ Because of the number of large hydroelectric projects under construction in the USSR, there is the likelihood that the latter may become the leader in control techniques in this field. Automation of thermal powerplants in the USSR, on the other hand, not only lags behind similar automation in Western countries but is believed to be falling farther behind as a result of the rapid rate of Western advances. A major cause of this lag is the inadequate supply of digital computers, which are needed to function as data-loggers and to control the production process. Soviet progress in automation of power system control also is retarded by a shortage of computers, 29/ although to a lesser extent than automation of thermal powerplants. The USSR has no powerplant that is computer controlled, compared with 12 in Western Europe and 60 in the United States. 30/

C. Economies of Scale

Reductions in labor requirements accompany the lower investment associated with economies of scale in thermal powerplants. Few more men are required to operate a 500-mw unit than to operate a much smaller unit. Planning criteria for the USSR show that as the size of the generating unit increases, the labor force required per megawatt decreases. With each doubling of capacity the labor force may be reduced by 30 percent to 60 percent, depending on the size of the units involved. The planned shift from 200-mw generating units to 300-mw generating units in the USSR by 1965 is scheduled to release 1,560 men for other activities. If carried out, this reduction in labor would produce annual savings of about 2 million rubles in wages.

Planned reductions in labor requirements per megawatt of installed capacity in the USSR, however, are less than current US achievements. Soviet data for thermal powerplants using 300-mw and 600-mw generating units call for 0.5 and 0.3 operational personnel per megawatt, respectively. Several US powerplants in 1960 were operating with less than 0.3 men per megawatt, and forecasts of future requirements reduce that figure by one-half. Failure to achieve greater reduction in personnel by installing larger units apparently indicates that the USSR does not plan as extensive a program of automation as will be prevalent in the United States. A fairly high degree of automation, however, will be necessary in the USSR. Use of larger generating units employing higher steam parameters requires that computer-controlled operations become more widespread, inasmuch as human judgment may be incorrect or may be too slow to avert damage to the generating unit.

APPENDIX

SOURCE REFERENCES

1. Avrukh, A. Ya. Problemy sebestoimosti elektricheskoy i teplovoy energii (Problems in the Cost of Electric Power and Heat Energy), Moscow, 1963, p. 8. U.
2. Electrical World, 57th ann rpt, pt 2, 27 Feb 61, p. 85. U.
Ibid., 61st ann rpt, pt 2, 22 Feb 65, p. 114. U.
3. Avrukh, op. cit. (1, above), p. 189, 226. U.
4. Federal Power Commission. Steam-Electric Plant Construction Cost and Annual Production Expenses, Washington, 1964, p. XI. U. (hereafter referred to as Steam-Electric Plant)
5. Ibid., p. XXVII. U.
6. UN. Annual Bulletin of Electric Energy Statistics for Europe, 1959, Geneva, 1960, p. 33, 41, 43. U.
Ibid., 1963, Geneva, 1964, p. 43, 57, 59. U.
7. USSR. Narodnoye khozyaystvo SSSR v 1963 godu (The National Economy of the USSR in 1963), Moscow, 1965, p. 159. U.
Ibid., 1961, Moscow, 1962, p. 217. U.
8. Teploenergetika, Sep 58, p. 3. U.
9. Elektricheskiye stantsii, Aug 59, p. 2-8. U.
10. Ekonomicheskaya gazeta, 22 Aug 64, p. 36. U.
Pravda, 20 Jan 65, p. 2. U.
Izvestiya, 18 Dec 64, p. 3. U.
Ekonomicheskaya gazeta, 20 Jan 65, p. 14. U.
Pravda, 25 Jan 65, p. 1. U.
11. Edison Electric Institute. EEI Pocketbook of Electric Industry Statistics, 1961 ed, New York, p. 19. U.
CIA. CIA/RR ER 65-21, Consumption of Electric Power in the United States and the USSR as an Indicator of the Standard of Living, Aug 65, p. 4. U.
12. Pravda, 7 Jun 63, p. 1. U.
13. Avrukh, op. cit. (1, above), p. 8, 144. U.
14. Pravda, 4 Dec 58, p. 3. U.
15. Promyshlennaya energetika, Feb 60, p. 42-45. U.
16. Finansy SSSR, Feb 63, p. 25-32. U.
17. Edison Electric Institute. Statistical Yearbook of the Electric Utility Industry for 1963, New York, Sep 64, p. 54-55. U.
18. Fridman, S.L. Voprosy sebestoimosti v energeticheskom stroitel'stve (Questions on the Cost of Power Construction), Moscow, 1962, p. 24. U.
19. Pravda, 11 Dec 64, p. 6-7. U.
20. Fridman, op. cit. (18, above), p. 24-25. U.
21. Melent'yev, L.A. Ekonomika energetiki SSSR (Economics of Energy in the USSR), Moscow, 1963, p. 104-105. U.
USSR. Tekhniko-ekonomicheskiye osnovi razvitiya teplofikatsii v energosistemakh (Technical-Economic Basis for Development of Thermification in Power Systems), Moscow, 1961, p. 14. U.

[p. 20 blank]

22. Elektricheskiye stantsii, Nov 56, p. 26, 28. U.
Ibid., Dec 59, p. 6-10. U.
23. Steam-Electric Plant (4, above), p. XIX. U.
24. Elektricheskiye stantsii, Jan 65, p. 4. U.
25. Ibid., Aug 59, p. 2-8. U.
26. Electrical World, 27 Feb 61, p. 85. U.
Avrukh, op. cit. (1, above), p. 8. U.
27. USSR. Promyshlennost' SSSR, statisticheskiy sbornik (Industry of the USSR: A Statistical Handbook), Moscow, 1964, p. 239. U.
Steam-Electric Plant (4, above), 13th ann suppl, Washington, 1960. U.
Ibid., 15th ann suppl, Washington, 1962. U.
28. Energetik, Mar 59, p. 1-5. U.
29. Elektrichestvo, Oct 64, p. 52-54. U.
30. Power, Oct 64, p. 74. U.