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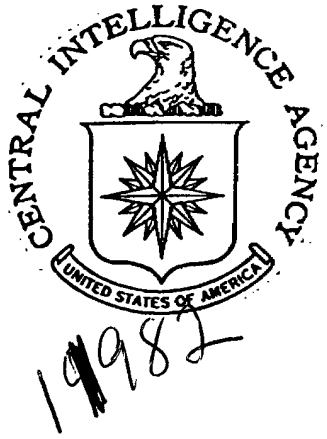

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INTELLIGENCE REPORT

PRODUCTION OF ELECTRONIC COMPONENTS IN THE USSR 1958–65

CIA HISTORICAL REVIEW PROGRAM
RELEASE AS SANITIZED

DIRECTORATE OF INTELLIGENCE
Office of Research and Reports

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FOREWORD

Electronic components (nonmechanical devices that amplify, switch, dissipate, or store electrical energy) are the basic building blocks for making electronic end equipment. Information on the level of production and the types of Soviet components available provides one approach to the study of the quality and the types of end equipment. For a detailed discussion of the Soviet electronics industry as a whole and for revised plans, see CIA/RR ER 64-17, Composition and Size of the Military Sector of the Soviet Electronics Industry, 1957-65, June 1964, SECRET.

The electronic components industry of the USSR in the period of the Seven Year Plan (1959-65) is surveyed in the present report, which supersedes previous publications of this Office on the subject. This report is oriented toward the study of components as an indicator of production of end equipment and includes discussion of administration and organization of the industry, patterns of production and consumption, and production technology. Areas of trade and scientific-technical intelligence are covered in more detail in other publications and are discussed here only briefly.

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PRODUCTION OF ELECTRONIC COMPONENTS IN THE USSR* 1958-65

Summary and Conclusions

Production of active electronic components** in the USSR is expected to rise from 170 million units in 1958 to approximately 1 billion units in 1965, an average annual rate of growth of 29 percent. The original Seven Year Plan (1959-65) for active components probably will be exceeded by 15 to 20 percent. The share of semiconductors in the total production will rise from 35 percent in 1958 to about 81 percent in 1965. Production of semiconductors throughout the Plan period will show an average annual rate of growth of 45 percent, from 60 million to 820 million units; in contrast, production of electron tubes will increase at an average annual rate of only 8 percent, from 110 million to 190 million units. Comparative rates of production for tubes and semiconductors in the US and the USSR are shown in Figure 1.***

In terms of units, exceeding the production plans for semiconductors more than compensates for the probably deliberate reduction in the rate of growth of production of electron tubes and creates the potential for increased production of electronic end equipment in support of revised goals of the Seven Year Plan. The only serious deficiency apparent is production of tubes for consumer entertainment equipment: defective tubes are being supplied to manufacturers of equipment in order to meet scheduled production plans. Steps that are being taken to improve this situation include the following: more intensive use of semiconductors in entertainment equipment; pressure for the improvement of production technology; and, for television picture tubes, construction of new plants and imports of production machinery.

For the Seven Year Plan, production of passive electronic components (resistors and capacitors) was originally planned to increase from 1 billion units in 1958 to 4 billion in 1965, but the Plan probably was increased. The low level of production technology in passive components at the beginning of the Plan period made large increases in productivity and output possible through modernization of existing plant without a corresponding increase in new construction. There is evidence that by 1962 domestic facilities for modernization became inadequate to supply the increased demand for passive components and that the USSR turned to countries outside the Soviet Bloc for imports of production equipment.

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* The estimates and conclusions in this report represent the best judgment of this Office as of 1 November 1964.

** Throughout this report, data on production of electronic components exclude selenium and copper oxide rectifiers. Data on distribution of electronic components, however, include all components produced domestically as well as net imports.

*** P. 2, below.

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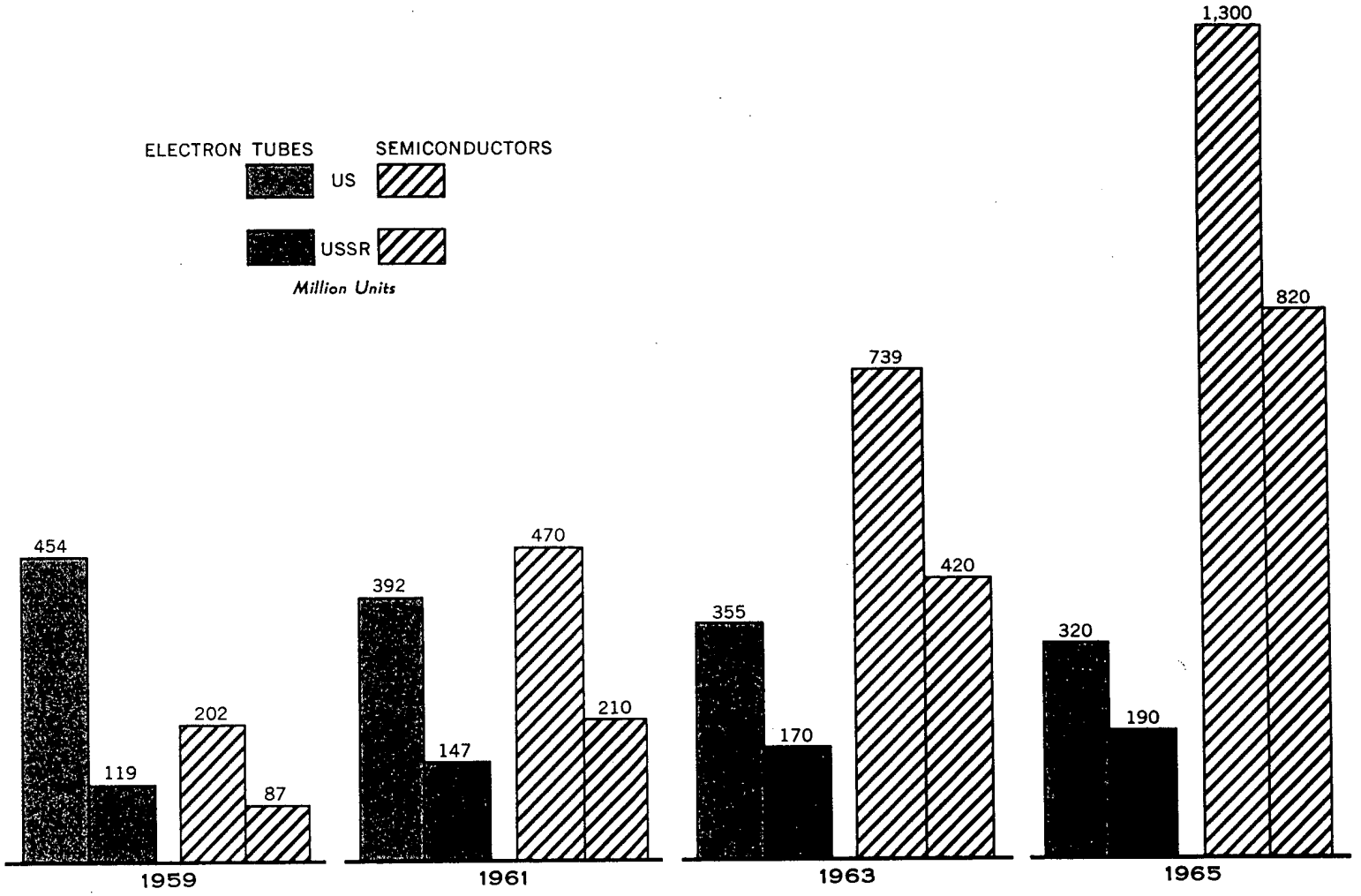
Figure 1

US AND USSR
ESTIMATED PRODUCTION OF ACTIVE ELECTRONIC COMPONENTS*
Selected Years, 1959-65



*Data for semiconductors produced in both the US and the USSR exclude selenium and copper oxide rectifiers. Data for both electron tubes and semiconductors produced in the US are based on factory sales.

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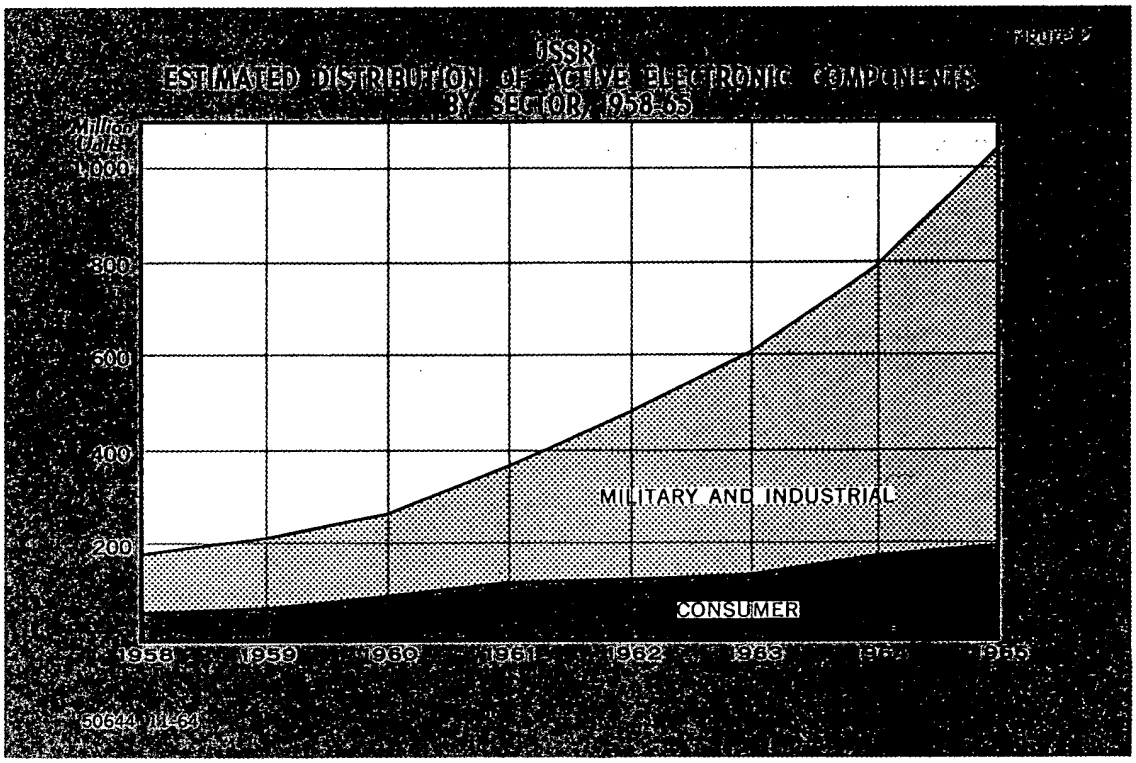
The quantity of active electronic components allocated to the consumer sector* shows an average annual rate of growth of 21 percent; components allocated to electronic end equipment used in the military and industrial sectors show an average annual rate of growth of 31 percent. The high rate of growth in the military and industrial sectors can support a substantially rising rate of production for original equipment as well as a high level of research and development activity. Distribution patterns for the consumption of active electronic components are shown in Figure 2.**



Soviet technological deficiencies in both the processing of raw materials and the manufacturing of components have created problems in semiconductors and in some of the more sophisticated types of passive electronic components. Although semiconductor diodes of average quality are widely used throughout the electronics industry, neither the quantity nor the quality of more advanced semiconductors, including transistors,

* The consumer sector includes radios, phonographs, and television sets. The industrial sector includes electronic instruments, computers, and civil communications equipment. The military sector includes electronic equipment associated with satellite and deep-space programs as well as equipment for use in military situations.

** The data on distribution in Figure 2 differ from the production data given above because Figure 2 includes the estimated production of selenium and copper oxide rectifiers and the net import of active components.

is adequate. Soviet technology in production of semiconductors is gradually improving and within a few years should permit the use of high-quality semiconductors in areas other than those having high priority. Transistors recently have begun to be used in substantial quantity in consumer entertainment equipment, implying a satisfaction at least of priority needs in the industrial and military areas for devices of average quality. The Soviet technological level in electron tubes is high, although there are problem areas resulting from the overly sharp cutback in the original planned rate of growth of production and the difficulties of manufacturers of tubes in meeting the rising demand without adequate materials or improved production equipment.

Soviet difficulties in electronic components, largely the result of the low rate of improvement of manufacturing technology, have been reflected in reorganizations of the industry. In 1961 a separate state committee was organized with responsibility for the design, development, and production of components. It is not yet clear whether this autonomous status will materially aid the industry in improving its technology, especially as production of materials and some specialized types of production equipment remain under the control of other industrial branches whose responsibilities for supplying the components industry are only a minor part of their assignments in the national economy.

I. Volume of Production

A. Active Components

The tendency for semiconductors to replace electron tubes in the USSR (as elsewhere) is shown by the average annual rate of growth during the period 1959-65 of about 8 percent for tubes and about 45 percent for semiconductors. (The estimated production of active electronic components in the USSR in 1958-65 is shown in Table 1.*) The net result is an average annual rate of growth of 29 percent for all active components. In comparison, on the basis of recently revised plans, it is estimated that the Soviet electronics industry as a whole will achieve an average annual rate of growth of about 20 percent during 1959-65. Production of active components in the US and the USSR is shown in Figure 1.** The comparison in Figure 1 is somewhat unfair to the USSR: the much smaller amount of electronic end equipment already produced in the USSR generates lower requirements for replacement tubes, and a much higher proportion of Soviet tubes is available for production of original equipment.

Output of semiconductors showed a tendency to increase much more rapidly than planned in the early years of mass production (since about 1955). The superseded Sixth Five Year Plan (1956-60) provided for an output of 30 million units in 1960; actual production was 125 million in that year. This high rate of growth continued through 1961 but is believed to have slowed down in later years. Even so, the goal of the Seven Year Plan of 350 million to 400 million units probably was achieved in 1963 and probably will be exceeded by at least 100 percent.

For the estimates for production of semiconductors it is assumed that the major source of expansion in 1964-65 will be domestically produced capital equipment. Assuming that imports of equipment add directly to rising domestic production of equipment rather than compensate for domestic deficiencies or replace older equipment, an even higher level of production may be expected.

Especially significant was the purchase of 33 automatic semiconductor slicing machines from Japan in mid-1964. 1/*** If these machines are fully utilized on production lines, they could support an additional increment to Soviet production of 300 million to 600 million semiconductors annually, and the USSR could approach US levels of production by 1965.

In contrast, the Seven Year Plan for electron tubes has been consistently underfulfilled. Probably less than 40 percent of the original goal of the Plan of about 500 million units will be fulfilled.

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* P. 6, below.

** P. 2, above.

*** For serially numbered source references, see Appendix C.

Table 1

USSR: Estimated Production of Electronic Components a/
1958-65

Million Units

Components	1958	1959	1960	1961	1962	1963	1964	1965
Active	170	206	250	357	480	590	770	1,010
Electron tubes	110	119	125	147	160	170	180	190
Semiconductors b/	60	87	125	210	320	420	590 c/	820 c/
Passive	1,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	4,000 d/

a. For methodology, see Appendix A.
b. Excluding selenium and copper oxide rectifiers.
c. A higher level of production could result from recent large imports of production equipment.
d. From the original Seven Year Plan (1959-65). The goal for 1965 probably will be exceeded.

This shortfall is without doubt deliberate (although perhaps somewhat more severe than advisable) and should be considered in the light of the compensating rapid increase in production of semiconductors.

Considering electron tubes and semiconductors together, production of active components in 1965 will exceed the original figure for the Plan by 10 to 20 percent, supporting the increased plans for the electronics industry as a whole. Moreover, these nominal figures understate the increase in output of end equipment made possible by the changing patterns of both component production mix and component consumption. The increased use of semiconductors reduces the demand for replacement spares and increases the percentage of production of components available for original equipment. In addition, the value of end equipment per component is greater for military and certain types of modern industrial equipment; the total value of output thus can be expected to rise more rapidly than production of components would indicate as the percentage weight of these two types of equipment increases.

In general, production of active electronic components has been sufficient to keep pace with the plans for the growing Soviet electronics industry. The most serious deficiencies are in the consumer entertainment sector, where the sharp cutback in the rate of growth of production of electron tubes has created a short supply situation. Sufficient quantities of receiving tubes and television picture tubes are being produced to meet plans for production of end equipment in this area, but only by using tubes of inferior quality or even defective tubes. For example, a spot check was made at one of the major plants manufacturing receiving tubes. Of the tubes ready for shipment to assembly plants, 31 percent were defective. 2/ The situation with respect to replacement tubes is no better; many articles in the press complain of delays in getting spare components, the need for waiting lists, and the quantity of radios and television sets that are inoperative because of tube failure -- not to mention the equally poor quality of the replacement parts even when they are available.

The USSR is known to have in mass production electron tubes of excellent quality; thus it would appear that efforts which could have gone into improving and increasing production of tubes have been diverted to semiconductors and that the military and industrial electronics sectors are being favored at the expense of the consumer.

Some attention has been paid recently to the problem of television picture tubes. There is a significant program underway to increase the number of shops for rebuilding picture tubes. Although this program will have some effect, it will not solve the fundamental problem of inferior construction of the original tube. It is doubtful whether the parts available to the rebuilding shops will be any better than those originally supplied to the tube plants. A more positive approach is construction of new facilities for production. One major plant is known to be under construction, and since 1963, negotiations

have been going on with both Hungary and the UK for the import of television picture tube plants. 3/

No comparable steps have been taken to improve the situation in receiving tubes for consumer entertainment equipment. A slight alleviation will result from the growth of production of transistor radios. Although over-all production of radios is planned to rise sharply during 1964-65, the increased use of transistor radios will reduce requirements for replacement receiving tubes for radios by about 5 million tubes, or about 50 percent of the current estimated requirements for replacement receiving tubes in the consumer sector. Nevertheless, the quality of components furnished to the consumer sector probably will not rise significantly in the near future unless a decision is made to bring capacity for production of tubes more into balance with demand either by new construction, by extensive modernization, or by improving the quality of materials furnished to components plants.

B. Passive Components

Production of resistors and capacitors was planned to rise from 1 billion in 1958 to 4 billion units in 1965. Although no production figures after 1958 are available, the plan probably has been increased to correspond with the new plans for active components.

The major source for increased production of passive electronic components has been intensive automation and mechanization. The rapidly increasing production of active components since 1960* and the consequent associated demand for resistors and capacitors probably have outstripped the rate of growth of production that Soviet internal resources can provide. Soviet interest in importing production equipment for passive components as reflected by both negotiations and actual shipments has risen considerably since 1962.

II. Administration and Facilities for Production

A. Historical Development

After World War II the USSR recognized that a well-developed electronic components industry would be necessary for the adequate development of a modern capability in electronics. Only a limited amount of specialization existed at that time, components being largely produced within the consuming plant.

The rapid postwar increase in production of electronic end equipment required additional output of components. This was achieved by the construction of specialized plants and the separation and expansion of components sections of existing plants. By 1954 the components industry was organized as a group of semiautonomous industrial

* See Figure 1, p. 2, above.

branches. Separate "subministries" (main administrations) of the Ministry of the Radiotechnical Industry (MRTI) administered production of various categories of components. The industrial reorganization of 1957, in which the MRTI was transformed into the State Committee for Radioelectronics (Gosudarstvennyy Komitet po Radioelektronike -- GKRE), did not alter the administration of manufacturing of components in relation to electronic equipment in general.

For some time the USSR had been dissatisfied with the low rate of introduction of new technology into manufacturing of electronic components. Hoping to rectify the consequent low productivity of manufacturing facilities and the difficulties in producing adequate quantities of advanced types of components, the USSR in March 1961 divided the GKRE into two new state committees. One, retaining the title GKRE, kept the responsibility for most electronic end equipment and systems. The other, named the State Committee for Electronic Technology (Gosudarstvennyy Komitet po Elektronnoy Tekhnike -- GKET), took over responsibility for components and related areas. Thus by 1961 the electronic components industry of the USSR had developed into an autonomous branch of Soviet industry with separate administration and specialized production facilities.

B. Administration

The chief specific responsibilities of the GKET for components appear to be three 4/: (1) the design and development of new components; (2) the development and introduction of modern manufacturing technology, including production machinery, for components; and (3) the primary ministerial-level responsibility for the supervision of production of components (shared with other All-Union and republican governmental organizations in the usual Soviet practice).

The establishment of the GKET does not seem to have had much effect on the problems of the electronic components industry -- the rate of development of production technology since 1961 has not been noticeably more rapid than in previous years. To a large degree this is the result of the diffusion of responsibility in the industries related to production of components. For example, although the GKET itself controls the actual production of components, the metallurgical industry is responsible for production of special metals and monocrystalline semiconductor materials. The chemical industry has the responsibility for solvents, phosphors, and synthetic materials. In spite of the interests and responsibilities of the GKET for modern production machinery and equipment, the machine building and electrical equipment industries continue to be responsible for the development of many specialized items of production equipment. These other industries have long been lax in servicing the needs of the electronics industry, a very small but important proportion of their total responsibilities in the national economy. As a result, although the GKET and organizations subject to it must share the blame, the satisfactory development of the

components industry has been retarded. Success in producing standard components in adequate quantity and quality for the consumer entertainment sector and in producing technologically advanced types for military and industrial use will depend largely on the degree of support that the GKET and its producing enterprises receive from other areas of the economy. 5/

C. Facilities for Production

1. Components

As already noted, the manufacture of components has tended to become more and more specialized. The majority of components are now produced in plants concentrating on one or a few types of components. This tendency toward a division of labor within the electronics industry has improved the efficiency of the components sector.

Electron tubes are primarily produced in specialized plants. In contrast, the very rapid increase of output of semiconductors after 1956 led to the setting up of production facilities in existing plants (mostly producers of components) in order to satisfy the demand. The current trend, however, is toward the establishment of separate semiconductor plants.

One holdover from the old system of producing components within the consuming plant is production of semiconductor diodes for electronic computers. These diodes are still produced in computer plants at a substantially higher cost and lower reliability than equivalent units produced in components plants. Some specialized types of diodes are not made outside computer plants. 6/ The increasing production of semiconductors by GKET enterprises will permit the transfer of production of computer diodes to the more efficient, specialized plants.

Several Scientific Research Institutes (Nauchno-Issledovatel'skiye Instituty -- NII's) also play an important role in production of active components. These NII's were set up to carry out research and development on specialized or advanced areas of components and, in some cases, have grown into important production organizations in their own right. For example, one of the most important is NII 160 near Moscow, a major producer of microwave tubes (klystrons, magnetrons, and traveling-wave tubes). Other NII's are active in the series production of newly designed components that have not yet been assigned to a plant and of some high-performance components for military use.

There has been very little new construction of plants in the electron tube sector during the Seven Year Plan. Several plants were converted or newly built for production of mercury rectifiers (used in welding, electric locomotives, and various other industrial applications), but the growing use of semiconductor rectifiers will make any further increase of production capacity unlikely in this area. In

addition, a television picture tube plant is under construction at present in Lithuania. 7/ Apart from these minor additions to total capacity for production of tubes, the modest increase in production of tubes has been accomplished through the expansion and modernization of existing plant.

New facilities for production of semiconductors have come into operation at a fairly steady rate. One or two new facilities have begun operating during each year of the Plan. Some of these plants are not yet producing at full capacity. These, together with other plants under construction, should provide for the continued high rate of growth of production of semiconductors and should compensate partly for the reduced rate of growth of production of electron tubes.

Resistors and capacitors are produced in specialized plants. Some passive components plants produce both, but the majority specialize in one or the other type.

There is very little evidence of any major new construction in the passive components sector, although new production areas have been added to some existing plants. The increase in output of passive components needed to support the growing Soviet electronics industry has been achieved by modernization of inefficient existing plant.

As an example of the possibilities of modernization, a major capacitor plant in the USSR more than doubled the value of its output in the period 1954-58 without any increase in production area. This was accomplished solely through an internal program of automation and mechanization using equipment designed and built within the plant (outside investment loans from Gosbank were required). Although these results were achieved before the beginning of the Seven Year Plan, the experience of the plant was to serve as a prototype for other producers and may be taken to indicate the potential for increasing output of passive components in the USSR without new construction of plants. 8/

2. Production Machinery

The responsibility in the USSR for the development of specialized machinery for production of components has traditionally belonged to components producers themselves. 9/ An extreme case is the capacitor plant mentioned above, which nearly doubled the value of its fixed assets in 4 years by installing machinery built within the plant.

A certain amount of machine building by a manufacturing plant is common industrial practice, but the USSR has relied excessively on this arrangement. The plants often lack the equipment and experience that would be available to a producer of specialized equipment for production of components. The fragmentation of activity among many small groups and the lack of exchange of experience have resulted in a duplication of effort that the industry can ill afford.

The inefficiency of these procedures is well understood in the USSR, and corrective measures are being taken. From 1950 through 1962, only seven plants had been built for production of specialized equipment. In 1963, construction was underway on four additional plants. 10/ Further attempts are being made to stress the responsibilities of other branches of industry, especially those controlled by the State Committees for Electrical Engineering and for Instrument Construction, Automation Equipment, and Control Systems.

Nevertheless, it is still reported that "almost all equipment used in the manufacture of electronic components is produced by the electronics [components] industry," largely by the "machine building shops and sections of all enterprises of the GKET." 11/ If new production enterprises for specialized equipment are successfully created and if the necessary support from other industrial branches is received, a significant improvement will occur in the productivity in components manufacturing and the reliability of the finished product. Above all, the ability of the USSR to produce large quantities of advanced types of components requiring the most complex techniques of production would be greatly enhanced.

III. Distribution

Total distribution of active electronic components in the USSR is rising at an average annual rate of 28 percent. The rate for the consumer sector is 21 percent, and that for the military-industrial aggregate is 31 percent. The estimated distribution of active components between (1) the consumer sector and (2) the military and industrial sectors is shown in Table 2* and Figure 2.**

Although the majority of active components used in consumer entertainment equipment still consist of electron tubes, output of semiconductors for use in original equipment as shown in Table 2 has been growing rapidly. On the basis of plans for the increased use of transistorized radios, production of semiconductors for original equipment for consumer entertainment will nearly equal that of tubes by 1965.

Germanium diodes make up the majority of semiconductor devices used in consumer entertainment equipment. These units are widely used in the signal circuitry of radios and television sets and have replaced selenium rectifiers in power supplies for television sets, although not in radios. Output of transistorized radios as a percentage of total production of radios is planned to rise from 26 percent in 1963 to about 45 percent in 1965. 12/ The resulting increase in the role of transistors in the consumer sector is shown in the following tabulation of requirements for transistors in original equipment for consumer entertainment (in million units):

* P. 14, below.
** P. 2, above.

1958	1959	1960	1961	1962	1963	1964	1965
Negl.	1	1	2	4	9	17	22

In the consumer sector, spares for replacement purposes as a percentage of total consumption of active components rose from 7 percent in 1958 to a peak of 10 percent in 1963. Because of the rising proportion of transistorized radios planned for 1964-65, requirements for spares as a percentage of the total are expected to decrease for these years, although still increasing in absolute magnitude. These figures help to explain the disparity between the USSR and industrial countries outside the Soviet Bloc in the relationship of total value of production of electronic equipment to output of components. For example, it is estimated that in 1962 the US had in operation 219.4 million radios, radiophonographs, and television sets; the comparable figure for the USSR was 41.1 million. 13/ Had the inventory of consumer equipment of the USSR been equal to that of the US in 1962 in quantity and composition, about 70 million active components for replacement would have been required compared with the actual figure of 12 million. The much smaller Soviet inventory of equipment already produced reduces considerably the Soviet demand for replacement parts. Thus, in spite of the high rate of growth of the consumer sector and the consequent rapid increase of sets in operation, the relative demand for replacement components is and will remain for some time much smaller than US experience applied to current Soviet production levels would imply.

The military and industrial sectors (including research and development activities) are the major consumers of semiconductors in the USSR, primarily in the form of germanium diodes. Soviet electronic computers have used semiconductor diodes in combination with electron tubes since the middle 1950's; limited production of fully transistorized equipment began in 1960-61. This area of industrial electronics is claimed to be second only to the radio-television industry in use of semiconductors. 14/ Civil communications equipment uses diodes and, to a lesser extent, transistors. Several new types of transistorized communications equipment, including (1) unattended repeater stations for cable and microwave communications and (2) voice-frequency telegraph multiplexing equipment, have been developed and are intended to go into production in the near future. 15/ This equipment, together with production of computers above the original Seven Year Plan 16/ and the growing need for military and space electronic equipment of good quality, should provide a ready market for the rising output of semiconductors.

Table 2

USSR: Estimated Distribution of Active Electronic Components, by Sector a/
1958-65

Million Units

Sector	1958	1959	1960	1961	1962	1963	1964	1965
Total	180	216	262	368	490	610	790	1,030
Consumer	52	63	92	120	129	139	173	195
Original equipment								
Electron tubes	35	38	53	63	71	71	81	90
Semiconductors	14	20	32	48	46	54	77	89
Replacement equipment								
Electron tubes	4	4	6	8	11	12	13	14
Semiconductors	Negl.	Negl.	Negl.	1	1	2	2	3
Military and industrial	128	153	170	248	360	470	620	840

a. For methodology, see Appendix A. The data in this table include all components produced domestically and net imports and differ from the data presented in Table 1, p. 6, above, which exclude selenium and copper oxide rectifiers. Because of rounding, components may not add to the totals shown.

IV. Technology

A. Active Components

1. Electron Tubes

The USSR produces in series all of the major types of electron tubes currently produced in other countries. Because of poor materials and because of production equipment that is relatively less modern, the USSR is technically deficient in some areas representing extremely high levels of performance. Soviet tubes also tend to be less reliable than equivalent units produced by countries outside the Soviet Bloc. However, the current Soviet state-of-the-art is adequate for production of most types of modern electronic end equipment designed around tubes.

The USSR has mastered the techniques of development and production of electron tubes and in some cases has been able to strike out along original lines. Several examples of Soviet capabilities can be given. In 1956 the USSR had in mass production subminiature tubes that easily exceeded US military specifications for similar types. 17/ Manufacturing techniques were used that were at that time in only experimental use in the US. Low-power traveling-wave tubes were reported to have been in operational use in military equipment as early as 1953. Although the USSR has exploited foreign technology in this area, it also has done independent work; an original Soviet-designed tube, the spiratron, aroused great interest when the tube was announced at an international conference in 1956. 18/ For several years the USSR has been producing miniature receiving tubes of original design and excellent quality using rod-type electrodes instead of the conventional thin wire. Because of their unusual construction, they offer the possibility of being used instead of either conventional vacuum tubes or semiconductors in many types of communications and navigation equipment, thereby improving the quality of the equipment without cutting into the supply of semiconductors.* 19/ These tubes would be a logical choice if it were decided to replace the obsolescent equipment used at present by the ground forces and if the quantity or quality of semiconductors were not adequate for this purpose.

Another interesting line of investigation, in this case still in the research and developmental stage, is in high-speed cold cathode gas discharge switching tubes.** This general type of electron

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* For some applications, electron tubes at present are preferable to semiconductors on a cost basis. Developments such as the Soviet rod-type tube and the nuvistor developed by RCA permit many of the advantages of semiconductors at reasonable cost. Over the long run, however, new types of semiconductors and lowered costs of production will reduce interest in unconventional receiving tubes.

** Gas discharge tubes conduct electricity by the movement of the electrically charged particles of an ionized gas rather than by the movement of electrons through a vacuum. The term [footnote continued on p. 16]

tube has long been used for standard voltage regulators, low-speed counting devices, and neon pilot light bulbs well known in the Soviet Bloc as elsewhere. The chief advantages of such a device in relation to conventional vacuum tubes derive from the absence of a heated cathode and the simplicity of both tube construction and required associated circuitry. The results are lower cost of equipment, much longer operating life, small size, better resistance to shock, and negligible power consumption. Traditionally these devices have not been widely used in applications other than the ones given above, because of the major disadvantage of low operating speed. Some work has been carried on outside the Soviet Bloc in highly specialized applications such as weapons fusing, but, largely because of the ready availability and low cost of semiconductors, interest in improving these devices for wider use as conventional circuit elements has been minor.

The attitude toward these devices in the USSR has been different. Since 1958 the Soviet press and technical publications have been paying considerable attention to the subject, giving extremely optimistic (and often exaggerated) estimates of the potential for cold cathode gas tubes and calling for their more rapid development and wider use. As a result of Soviet research this type of electron tube has been developed to the point where it is a technically feasible alternative to the use of the conventional type of active component to an extent not before believed to be practical. Indeed, the Soviet press has called it a "third path" in the development of electronics, along with vacuum tubes and semiconductors. 20/

The most interesting Soviet development in cold cathode tubes was the announcement in 1962 of a series of five-electrode, six-electrode, and seven-electrode tubes with de-ionization times of only a few microseconds. 21/ Apart from the rapid speed of operation permitting microsecond switching, the multielectrode construction permits using one gas tube to replace several vacuum tubes or semiconductors, with substantial savings in both active components and the necessary associated resistors and capacitors. Tubes of this type suggest many potential uses in moderate-speed digital circuitry for programed industrial control equipment, telephone switching stations, and small data-processing units for use in individual agricultural, industrial, financial, and planning organizations.

It is doubtful whether these types of electron tubes would arouse the interest of designers of equipment outside the Soviet Bloc to the extent that they have in the USSR. The only remaining advantages over semiconductors (ease of servicing and lower cost) will disappear as advanced miniaturization techniques involving thin films and solid circuits become more widespread. These tubes appear much more attractive

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cold cathode indicates that, unlike most vacuum and many gas discharge tubes, the cold cathode tube requires no external electrical source of energy to heat the cathode as a source of electrons.

in the USSR, with its many problem areas in the quantity and quality of production of active components. Their widespread use would aid in solving both types of problems by bringing the demand for vacuum tubes and semiconductors closer to the actual capacity to produce and by dampening the tendency to produce defective components merely to meet production plans.

Whether or not high-quality cold cathode gas tubes come into wide use will depend largely on the successes in improving production technology in the materials and conventional component areas of manufacturing. It is doubtful whether the USSR will attempt the painful process of developing an entirely new technique of electronic circuit design and of reeducating its technical personnel as long as there is any hope of improving the status of vacuum tubes and semiconductors in a reasonably short time.

2. Semiconductors

The USSR has developed an excellent theoretical capacity and a research ability in semiconductors that is at least adequate. Nevertheless, the translation of scientific achievements into mass production of devices has been and remains a serious problem. Although the USSR has published the results of experimental research in almost all areas of materials and structures currently of practical importance, indicating an ability to fabricate advanced devices on an experimental scale, it in general remains 3 to 5 years behind the state-of-the-art outside the Soviet Bloc in production models of readily available devices.

Structurally, Soviet semiconductors in series production appear to be restricted to unsophisticated point-contact, alloyed, and diffused junction types. The equally conventional grown junction process is not used, probably because, in this process, formation of the junction and purification of the material are simultaneous. Because material purification is the responsibility of the metallurgical industry, the device fabricator would have no control over the junction forming process nor, therefore, over the characteristics of the finished device. The metallurgical industry has never shown the ability to service adequately the demands of semiconductor producers, and the choice of junction forming techniques other than growing gives enterprises outside the control of the GKET the minimum responsibilities possible under the present system of organization.

There is no evidence of mass production using more advanced structures and processes such as mesa, planar, or epitaxial types. The result is a technological lag relative to countries outside the Soviet Bloc, both in terms of maximum frequencies of operation available and in the power available at a given frequency. This deficiency is due to industrial inadequacies in equipment for materials processing and production rather than to any lack of knowledge, and the existence of

highly classified institutes with some production capabilities makes it possible that there is small-scale production of more advanced types for missile applications and especially for space applications.

In all countries the overwhelming majority of semiconductor devices are either germanium or silicon types. Germanium historically was the favored material because of ease of processing,* and even today, apart from its lower cost, it has certain properties that make it preferable to silicon in certain applications. Silicon devices, on the other hand, can operate at higher levels of power, are more stable, and resist higher temperatures than germanium. At present these advantages are accompanied by higher cost, although improved methods of production and increasing economics of scale are bringing silicon into a more competitive cost position. In spite of the higher cost, silicon units outside the Soviet Bloc are becoming more and more widely used when performance superior to germanium is required or when cost of components is only a minor consideration, as in military and space applications.

Because of a combination of factors, Soviet technology in silicon lags even farther behind world standards than does germanium. First, silicon of quality adequate for modern semiconductor devices is inherently more difficult to manufacture and process than germanium. Second, the USSR by its own admission devoted a great deal of effort to the study of semiconductor compounds to the detriment of advances in silicon technology. 22/ These factors, combined with a lack of modern production machinery, have resulted in the use of germanium for the majority of semiconductors operationally used in electronic equipment.

Little evidence of improvement was seen in silicon technology from 1958 (when silicon transistors and junction diodes were placed in series production) until 1963. In that year a number of new types of high-speed switching diodes, industrial power rectifiers, and, for the first time, four-layer devices were announced, reflecting substantial improvement over previous levels. Several new types of silicon transistors were introduced in 1964. Their characteristics continue to indicate a lag of at least 5 years behind standards outside the Soviet Bloc. 23/

* The series production of silicon point contact diodes in the USSR for use as radar mixers and detectors dates from the early postwar period and preceded production of germanium types. These polycrystalline diodes are roughly similar in function to the crystal diodes used in early radios before the invention of the vacuum tube, and they are far easier to manufacture than the more versatile monocrystalline transistors and diodes. Comments throughout this report on the quality of semiconductor materials refer to monocrystalline material or polycrystalline material of high quality intended for processing into the monocrystalline state.

The USSR is adequately supplied with mineral sources for semiconductor materials, but the difficulties in refining and purifying have been reflected in imports. In the 9-month period from December 1961 through August 1962 the USSR imported 9,150 kilograms of purified polycrystalline germanium. 24/ This amount is estimated to be sufficient for production of about 35 million devices, or 11 percent of total production of semiconductors in 1962. All of this large amount may have been immediately processed into devices, but the material more probably was stockpiled for use throughout a longer period to make up the deficiencies of the domestic metallurgical industry. In either case the transaction illustrates Soviet difficulties in materials processing.*

In addition to the large import of germanium mentioned above, the USSR has taken an active interest in importing, from countries outside the Soviet Bloc, production machinery for semiconductors. Since 1959, and especially since 1962, a steady and increasing volume of negotiations and actual purchases has been noted, ranging from specialized equipment -- for example, crystal pullers, electron-beam welders, and furnaces -- to complete production processes. All phases of the production cycle are involved, from material purification to device fabrication. Negotiations have been more extensive than actual shipments, partly because several sources may be asked to bid on the same order and partly because of the international embargo on much of this equipment.

B. Passive Components

The USSR produces in quantity almost all types of resistors and capacitors manufactured outside the Soviet Bloc. In general, tests and catalog data indicate that for the newer and more complex types construction is only adequate and the range of values available is not large. Thus the Soviet designer of equipment is less well favored than his non-Bloc counterpart, but careful design of circuits and layouts can minimize these deficiencies to a large extent. It is also to be expected that as the USSR gains experience in the manufacture and use of the newer types, the quality and range of component values available will improve.

The USSR has available for general-purpose applications several versions of carbon film, carbon composition, and wirewound resistors. They are equivalent to similar units produced outside the Soviet Bloc. One point of divergence between US and Soviet practice is the use of the carbon film type in the USSR as the standard resistor of average quality. In the US, composition types are used for this purpose; carbon film resistors are restricted to high-precision or low-noise applications and are several times more expensive. Because there is no need for such

* Imports of silicon by the Soviet Bloc are severely restricted by the embargo of the NATO countries and Japan on the better grades of material of semiconductor quality.

high quality in a general-purpose resistor, the USSR is able to manufacture at a low cost film types equivalent in performance to US standard composition types.

In addition to general-purpose resistors, the USSR produces several high-quality types. Precision carbon film, borocarbon, metal film, and wire-wound resistors are available in series when their various special characteristics are needed. Microwire resistors with a tolerance of up to 0.05 percent became available in 1961. 25/

The USSR also produces most contemporary types of capacitors. Only polyester film (Mylar) is conspicuously absent. The standard paper, mica, ceramic, aluminum, and polystyrene types are in wide use, with Teflon, vitreous enamel, and tantalum available for special applications.

The use of Mylar as a capacitor dielectric permits production of moderately priced general-purpose devices with a reduced size as well as an extended range in temperature. The lack of Mylar types in the USSR often requires either the use of more expensive high-temperature capacitors or a lesser degree of miniaturization than is common outside the Soviet Bloc.

As in the instance of semiconductors, the USSR has been actively seeking production equipment from sources outside the Soviet Bloc. Since the latter part of 1962 a number of negotiations have been observed dealing with machinery for production of metal film resistors and ceramic and electrolytic capacitors. Attempts to import production equipment for Mylar film of electronic grade as well as the film itself (both under international embargo) have been noted since this material came into wide use for capacitors in the late 1950's.

C. Miniaturization

Circuit design in the USSR remains conventional from the point of view of miniaturization. The use of subminiature electron tubes; semiconductor diodes, printed circuits; miniature passive components; and, to a lesser extent, transistors is becoming fairly common. In addition to the simple substitution of smaller components for larger components, high-density packing techniques that minimize intercomponent wiring and empty space are used in more sophisticated equipment. These high-density circuits are not manufactured in standard packages but are specially designed and built for each individual model of equipment.

At a more advanced level the USSR has a limited capacity to produce micromodules. These devices are made of thin insulating plates of uniform size, each with a conventional although extremely small semiconductor device or an individual passive component formed by the deposition of thin films. The resulting plates are stacked vertically

and interconnected. There is evidence that micromodules are in operational use, probably in high-priority missile and space projects and in diagnostic radiocapsules, but it is doubtful whether the present level of technology of mass production will permit widespread use of micromodules even in military applications for several years. There are no indications that the USSR has in operational use still more complex techniques of microminiaturization. 26/

APPENDIX A

METHODOLOGY

1. Production

The volume of Soviet production of electron tubes shown in Table 1* for the period 1958-61 was taken from official Soviet sources. 27/ Production of tubes in the RSFSR during the period January-June 1962 was used as an index of total Soviet production in 1962 on the basis of the experience of previous years. 28/ The rate of growth in 1961-62 was projected through 1965, and the results derived for 1962-65 were rounded to two significant digits. The original Seven Year Plan forecast that production in 1965 would be 4.5 times the level in 1958. 29/

Production of semiconductors in 1958 and 1960 was given by unofficial Soviet sources. 30/ Production in 1961 was reported officially to have been 3.5 times that in 1958. 31/ The output in 1959 was estimated by assuming a constant rate of growth for 1958-60. According to Soviet sources, production rose 68 percent in 1961 and was planned to increase 33 percent in 1963. 32/ The increase in 1962 was estimated to be 50 percent. Output in 1964-65 was estimated by assuming an annual rate of growth of 40 percent based on increments to plant capacity and the experience of previous years. Figures derived for 1962-65 were rounded to two significant digits. The original Seven Year Plan for semiconductors apparently underwent several changes in 1958-59, and there are several contradictory figures. The most recent figure, indicating a planned output of 350 million to 400 million in 1965, was taken as reflecting the final decision on the Plan. 33/

Rates of production for semiconductor devices (poluprovodnikovyye pribory) have been given for various years of the period 1950-65 in the Soviet press. The contents of this category have never been strictly defined. Assuming that this statistical reporting category has not been redefined over the years, the rates of production in the early 1950's -- for example, 81,000 units in 1950 34/ -- appear too small to include selenium and copper oxide rectifiers. On the other hand, these rates are reasonable for production of point contact diodes.** The rates of production for "semiconductor devices" as given in Soviet sources are estimated to include all types except those made from selenium and copper oxide.

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* P. 6, above.

** See the footnote on p. 18, above.

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2. Distribution

a. Total

The total production of components as derived in the preceding section does not reflect production of selenium and copper oxide devices or the effects of foreign trade and, therefore, somewhat understates the quantity of devices actually available for use. Production of selenium rectifiers for radios was calculated by the method discussed in b, below; these figures were combined with estimates for industrial consumption of selenium and copper oxide rectifiers and available information on trade. The result represents an addition to the total production, which rises in absolute terms during the Seven Year Plan period but declines from 6 percent of production in 1958 to 2 percent in 1965.

b. By Sector

Annual actual or planned rates of production for specific models of Soviet consumer entertainment equipment were taken from a large number of Soviet sources. Circuit diagrams or descriptions of the equipment were used to determine the component complement for each set. The resulting figures were then added and adjusted to total rates of production for consumer equipment. For example, if in a given year there were plans to produce 600,000 television sets of specified types requiring 8 million semiconductor diodes but if 900,000 sets were actually produced, it was estimated that 12 million diodes were used. This type of calculation was carried out for transistorized and nontransistorized radios, television sets, and phonographs and for picture tubes, receiving tubes, semiconductor diodes, selenium rectifiers, and transistors. The results were combined to give total requirements for active components for original equipment for the consumer sector.

Requirements for replacement components were estimated by applying, to the total amount of entertainment equipment in operation, data from Soviet sources on rates of failure of consumer equipment and the percentage of failures due to various types of components. 35/ Consumption by the military and industrial sectors combined was derived by subtracting consumer consumption from the total.

APPENDIX B

GAPS IN INTELLIGENCE

On the aggregate level the lack of any firm statistical information since 1958 precludes any estimates of current or future production of passive components. Statistics on production of electron tubes were discontinued in 1962, but the fairly stable nature of this sector of the components industry permits projections through 1965 with a fair amount of confidence. There is sufficient information available to estimate Soviet production of semiconductors through 1963. Future increases in production depend on successes in advancing the technologies of processing and manufacturing materials and in improving, through imports or domestic efforts, the supply of specialized equipment for production of components. Information on current Soviet plans for production of semiconductors or details of production facilities, existing and planned, would therefore greatly aid in reliably projecting estimates of production of semiconductors through 1965.

In the area of active components the most serious gap in intelligence is the lack of information on the composition of the categories of electron tubes and semiconductors. Data on the subdivision of these categories, by type (transistor, diode, transmitting tube, and the like), by function (replacement or original equipment), and by distribution between the military and industrial sectors, would provide much useful information on current and future developments in the Soviet electronics industry as a whole as well as its components subsector.

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