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Level of Technology and Production of Semiconductors in the USSR and East Europe

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I. USSR

A. General

The rapid growth in the production of semiconductor devices in the USSR is a national goal of high priority. In recent years the output of semiconductors has grown at very high rates (it is estimated that output increased by 40 percent in 1966 compared with 1965), and statements by leading officials of the electronics industry attest to plans for continued rapid growth during the current Five Year Plan (1966-70).

B. Technology

Although the production of transistors and integrated circuits (IC's) in the USSR currently enjoys a high priority, Free World observers find unusual trends in the direction and rate of development of such production. The USSR has been slower than the industrial countries of the Free World in replacing tube components with transistors in industrial instruments, computers, communications equipment and probably in military equipment. Manufacturers and users of electronic equipment appear to prefer the use of tubes because of their established reliability. Much of the production of Soviet garden variety transistors is of uncertain quality, probably caused by marginal standards for acceptance testing. The cutoff point for acceptance of general purpose transistors probably is set too low and some devices of questionable reliability may not be rejected. The transistors with the very best parameters are probably set aside for military-space use. Numerous complaints about the reliability and assortment

of semiconductors, and about delays in their delivery appear in the Soviet press. Soviet semiconductors taken from consumer entertainment equipment have been examined by US components experts and found to be no more than adequate for their intended purpose.

It is somewhat surprising that at this time the USSR should not be engaged in large scale production of silicon transistors and integrated circuits. Silicon is the basic material for integrated circuit technology, a technology that Soviet planners admit is crucial to advanced electronics programs, particularly for the development of fast computers with large memories. The explanation for the apparent dearth of silicon transistors and IC's may be simply that the USSR has had difficulty in developing commercial-scale production processes and equipment. There is convincing evidence that Soviet semiconductor producers are quite anxious to obtain information and equipment for integrated circuit production either directly from US producers or indirectly from their overseas licensees in Western Europe and Japan. There is evidence that the Soviets have bought IC's from a large electronics firm in the Netherlands.

The extent of availability of high purity silicon in the USSR cannot be determined from available evidence. In 1966, the USSR offered for sale and sold internationally some small amounts of transistor-grade silicon. On the other hand, most of the silicon devices made in the USSR appear to be diodes and rectifiers, and for this use silicon materials need not have the high purity required for transistors.

C. Production

Analysis of the few officially published statistics available indicates that the gross output of semiconductors in the USSR in 1966 was about 1.1 billion units. Assuming a rate of rejection of finished devices of about 50 percent (rates of up to 75 percent have been reported by Free World visitors to Soviet semiconductor plants), the production of useable devices in 1966 probably was on the order of 500 million units or about 25 percent of US production in that year. Superficial evidence indicates that most of the Soviet semiconductors are diodes. Moreover, Soviet semiconductors in mass production appear to be of the relatively ordinary point contact, alloyed, and diffused junction types. There is no evidence of mass production of epitaxial mesa and planar types.

D. Application of Semiconductors

Semiconductors appear to be replacing conventional tubes at a slow pace. Certain items of transistorized and miniaturized consumer, industrial, and communications equipment have appeared in the USSR, but the value of this product is relatively small compared with the value of the total output of the electronics industry. Moreover, very little transistorized military equipment has been noted. It is suggested that the self-sufficiency which the Soviets claim for their semiconductor industry is only justified because only a minor part of their electronic equipment is designed to incorporate semiconductors. Western observers have noted that some of the very latest Soviet equipment (for example, that displayed at Expo '67 and the Paris Air Show) contains only tubes.

E. Production Machinery

In contrast to the mediocrity of its semiconductor devices, the semiconductor production machinery that the USSR has exhibited at trade fairs in recent years appears to be quite modern. This machinery is often cited as an indication of advances in Soviet technology because it is presumed the USSR would not export its best -- hence must have some better equipment which it is concealing. In many cases, however, the machines are direct copies of US equipment, and the actual capabilities of the machines, as well as their availability in the USSR, are known only by Soviet claims. It is known that the USSR has imported semiconductor production machinery from the Free World in recent years. Moreover, there are continuing attempts (and actual orders) by the USSR to obtain more specialized production equipment and complete production processes from the Free World and, in some cases, indirectly from the US. It appears that the USSR, far from being satisfied with its semiconductor output would like to expand its production with large inputs of Free World production equipment. These facts are not consistent with Soviet claims that the USSR currently maintains a self-sufficient semiconductor industry.

II. EAST EUROPE

A. General

The total output (including rejects) of semiconductors in East Europe in 1966 is estimated at about 81 million units, or about 7% of the Soviet level of output. In all respects: size and assortment of output, scope of research and development activity etc., collectively the semiconductor industries of East Europe cannot approach that of the USSR.

In theory, the Council for Mutual Economic Assistance (CEMA) directs cooperation in semiconductor development and production throughout East Europe under the leadership of the USSR. Under CEMA, the Academies of Science of the member countries have working agreements for the exchange of research and production technology. Czechoslovakia has been designated coordinator for semiconductor research within EE; East Germany was tasked to provide semiconductor materials, prototype equipment and the technology for the production of semiconductor devices; Czechoslovakia and Poland, are responsible for providing essential laboratory grade chemicals for semiconductor research to all EE countries except East Germany.

In practice, however, the exchange of information between EE countries is effective only when it is mutually desired. The exchange of information with the USSR is governed by other considerations. For example, the USSR had agreed in CEMA to provide guidance and assistance in semiconductor production to other members. Experience has shown, however, that cooperation with the USSR is frequently a one-way street. The USSR has tended to incorporate the best results obtained by the other member countries and to assign such tasks to them as would benefit its own semiconductor program,

including the designation of products to be manufactured in specific factories. Over time, member countries have learned to protect their research programs against unrequited exploitation not only by the USSR, but also by the other CEMA countries. The result is not cooperation and specialization, but isolation and duplication of effort. The effectiveness of CEMA is further diluted by restrictions on the movement of scientists and personnel within and between countries. This greatly reduces the exchange of ideas. The mobility of people and the transfer of ideas have been extremely important to semiconductor development in the US.

According to present indications, not only are Czechoslovakia and East Germany producing semiconductors, but Hungary, and, to a certain extent, Poland have developed some competence in their production. It is believed that these countries now have sufficient materials, funding, and qualified scientists, to carry on their own limited research and development programs, independently of CEMA assistance.

To a large extent, however, the success of future programs in all the East Europe countries may hinge on their ability to acquire equipment and technology from the West. During the early 1960's Bulgaria, Poland and Rumania obtained equipment and technological assistance from Great Britain, France, and Japan for the establishment of commercial scale production of general purpose germanium devices. By 1966 these countries were producing germanium transistors that were only slightly under Free World quality. It has been reported that 80 percent of the semiconductors currently produced in East Europe are made of germanium, and that these are mainly diodes. Virtually all of the silicon devices produced in East Europe are

power diodes. Czechoslovakia and East Germany produce a very few silicon transistors. At present these two countries are developing and attempting to procure semi-automated equipment to permit commercial scale production of integrated circuits.

B. Bulgaria

Bulgaria, the least important producer of semiconductors in East Europe, produced about 2 million semiconductor devices in 1966. Production of semiconductors in Bulgaria effectively began only in 1965 with the activation of a new plant in Botevgrad, built, equipped, and licensed by the French firm Compangie Generale de Telegraphie Sans Fils (CSF), to produce germanium transistors and diodes. These semiconductors are apparently of acceptable quality, and a small number are currently being exported to other Communist countries. The plant will satisfy one-third of Bulgaria's domestic needs, when in full production.

A limited semiconductor research and development program has been carried on in Bulgaria since about 1963. In September 1966, at the Plovdiv Fair, Bulgaria displayed silicon planar devices for operation in the megahertz region; it was claimed that these were produced domestically. In 1967 Bulgaria plans to produce tunnel diodes on a limited scale at the Semiconductor Laboratory in Sofia, and silicon rectifiers and diodes in new facilities at Botevgrad. These new facilities are reportedly being designed with Soviet assistance, and probably will be outfitted with Soviet equipment as well.

C. Czechoslovakia

In 1966, Czechoslovakia produced an estimated 11 million semiconductors,

more than double its 1963 output. A new plant, reportedly equipped with Soviet machinery and organized with Soviet technical assistance is scheduled to begin operations in the fall of 1967. It is estimated that, by the end of 1967, the annual rate of production of semiconductors will have nearly doubled compared with the previous year.

Czechoslovakia appears to be able to meet current domestic requirements (which, with the exception of consumer radios and TV's, are not large since end-equipments are only beginning to be designed around transistor technology) with a residual available for export. However, the quality of its semiconductors, and of transistors in particular, is below that of garden variety general purpose semiconductors produced in the West. Semiconductors are still produced at a relatively high unit cost since the home market is still relatively small. Ultra high frequency transistors must be imported.

In part, the quality of Czechoslovak semiconductors has been influenced by the lack of modern production equipment and by the relatively poor quality of available supplies of silicon and germanium. In prior years, Czechoslovakia depended upon imports of silicon and germanium from the USSR which were generally of low quality. However, Czechoslovakia now has the essential technology to produce monocrystalline silicon pure enough for general purpose semiconductors.

In addition to general purpose types, Czechoslovakia now produces, on a small scale, backward bias and tunnel diodes as well as epitaxial and planar devices using both germanium and silicon technology. Field effect transistors and varactors are scheduled for limited production by the end of 1967.

Czechoslovakia may soon become self-sufficient in the production of general purpose semiconductors of adequate quality, but will continue to require outside sources of supply for high performance and special types of diodes and transistors.

D. East Germany

In 1966, East Germany produced about 40 million semiconductors, accounting for nearly half of all the semiconductors produced in East Europe. In addition to high frequency mesa germanium transistors, 5 watt silicon audio frequency devices and silicon milliwatt drift transistors, all of which have been in production since about 1963, East Germany now produces, and reportedly is also producing for the USSR, field effect transistors, high power rectificers, solar cells and MOS/MIS transistors. It also produces silicon zener diodes and silicon planar teardrop transistors. A recent technical evaluation of these latter devices in the US indicates that East German state-of-the-art in silicon planar technology is at the level reached by the US in 1960 and that the devices are made in small lots.

East German semiconductor research and development is coordinated by the Institute for Semiconductor Technology of the East German Academy of Sciences at Teltow. Part of the activity of this institute is devoted to acquiring and copying Free World semiconductor devices. East Germany copies and reproduces high frequency transistors that are embargoed by COCOM and imports low frequency general purpose types that are not embargoed. These can be imported at prices below the level of domestic manufacturing costs and are more reliable than domestic transistors.

The East German semiconductor industry has been built on the basis of Western technology. The main semiconductor plant at Frankfort/Oder, for example, attempted to begin transistor production on the basis of Soviet technology which proved to be faulty and which the East Germans later learned had been abandoned in the USSR. Frankfurt/Oder was re-equipped by about 1963 with production machinery from the UK (this machinery, purchased at a 50 percent premium, turned out to be obsolete; reject rates on the order of 80 percent were reported). East Germany continues to import some semiconductor manufacturing equipment from the Free World, but is increasingly developing its own because of the difficulties COCOM imposes on procurement from the West.

Production capacity in East Germany is being expanded and modernized to meet East German needs for both general purpose and advanced type semiconductors. However, dependence on Free World sources of supply for high quality general purpose transistors is expected to continue for the immediate future. East Germany has developed some semiautomatic machinery for the production of thin film micro-circuits, which are believed to be suitable for computer applications.

E. Hungary

The production of semiconductors in Hungary is concentrated in two plants of the United Incandescent Lamp firm: Gyongyos Semiconductor Plant, which appears to have been equipped, in part, with production machinery from Great Britain; and the United Incandescent Lamp Plant, Budapest. Production is growing steadily although the level of output in 1966 was less than 10 million units.

Hungarian radio and TV plants have made periodic attempts to utilize domestic semiconductors, but the poor quality of the devices has made large supplemental purchases from the West necessary. Moreover, the small assortment of transistors and their relatively high price, which makes them non-competitive with tubes, has further discouraged their use by domestic industry. It is believed that Hungary currently satisfies no more than half of its domestic requirements for general purpose semiconductors, and that dependence on imports, not only of advanced devices but also of general purpose devices, will continue over the next few years.

Until recently, Hungary's research on semiconductors was limited to studying and reproducing on a laboratory basis the newer devices appearing in Free World markets. It was only as recently as 1966 that Hungarian research institutes started to do original work on semiconductor development. Research is now proceeding on materials technology, the development of high frequency transistors, high current silicon rectifiers, the development of mesa and planar transistors fabricated from silicon, and on production technology, which was, and is, Hungary's most pressing problem.

Reports indicate that Hungary would like to purchase production lines and processes from the West to expand and modernize its production facilities. In 1966 Hungary, through West Germany, requested a tender for a US plant to manufacture germanium mesa transistors at the rate of one million devices per year. The facilities were to include the latest equipment for production, testing and evaluation of product.

F. Poland

All semiconductors produced in Poland are manufactured by the TEWA Semiconductor Factory. It produces alloy and diffusion type germanium diodes and transistors, rectifier diodes, and a few types of silicon diodes in limited quantity. Substantial quantities of semiconductors are imported from the Free World and from other Communist countries to compensate for the relatively narrow range of devices that are produced domestically.

By its own admission, Poland is far behind Free World countries in the development and production of semiconductors. The quality of Polish produced devices does not measure up to Free World standards. Nevertheless, according to a technical evaluation made in the US, Polish germanium transistors are fully adequate for use in low frequency civil electronic end-items.

Substantial research on semiconductors has been underway in Poland since 1962 and some original studies have been carried out on transport phenomena. In addition, the University of Warsaw claims to have developed new methods of diffusing dopants into N-type materials. In 1966, the Baden Institute for Nuclear Research, Warsaw, developed a separation and recovery process for the extraction of germanium from its compounds. Up to this time, Poland had imported all the germanium required by its semiconductor industry.

While Poland could clearly benefit from Free World assistance, there is no evidence of any major effort to purchase Free World plants or manufacturing licenses.

G. Rumania

Series production of semiconductors in Rumania began in 1962, when

the plant at Baneasa went into operation. This plant was reported to have been established with the help of French, Italian, British and Japanese technicians and equipment. It produces general purpose germanium transistors and diodes under French license. A small number of the transistors produced have been given French transistor labels for sale in France. Within Rumania, the domestically produced semiconductors are used mainly in civilian radios and, to a lesser extent, in electronic equipment for the Rumanian military establishment.

The quality of semiconductors produced in Rumania for general purpose civil applications is, reportedly, very poor. In 1964, for example, transistor radios produced for export fell far below standards and, in fact, could not even be sold locally until fitted with imported transistors and diodes (from Japan and Czechoslovakia). Severe complaints of the quality of the semiconductors have continued up to the present. There is some indication that a small number of semiconductors destined for the military and for export come under more rigid quality control, but these are believed to be still of doubtful reliability.

All the evidence suggests that without a further infusion of imported equipment and technology, progress in the production of high quality devices in Rumania will continue to be slow. In 1967 US industry was approached to supply Rumania with the equipment and technology to produce approximately 3 million semiconductors per year of advanced types. This equipment currently under embargo, would enable Rumania to produce high frequency germanium and silicon devices, using mesa and planar construction techniques.

Table 1

Estimated Gross Production of Semiconductor Devices

in the USSR and Eastern Europe*

(Millions of Units)

	1964	1965	1966	1967
USSR	590.0	820.0	1,100.0	1,540.0
EASTERN EUROPE	41.6	55.3	81.0	128.6
Bulgaria	--**	1.5	2.0	3.0
Czechoslovakia	6.5	8.4	11.0	20.0
East Germany	19.0	24.0	40.0	55.5
Hungary	6.4	7.7	9.6	12.0
Poland	6.7	7.7	12.4	20.1
Rumania	3.0	6.0	6.0	18.0
GRAND TOTAL	631.6	875.3	1,181.0	1,668.6

* Gross production includes rejects.

** Pilot production.

III. ROLE OF THE FREE WORLD IN THE DEVELOPMENT OF THE SEMICONDUCTOR INDUSTRIES OF EAST EUROPE AND THE USSR

A. East Europe

The semiconductor industries of East Europe are based, in part, on obsolescent equipment and technology acquired in the Free World. Moreover, the quantity, quality, and assortment of domestically produced semiconductors has been, and is, so wholly inadequate that large quantities of Western devices are imported annually. While overall statistics on the volume of East European imports of semiconductors from the Free World are not available, it is reported that, in many East European countries, Free World imports account for more than 50 percent of the stock of useable general purpose devices.

The fact that advanced semiconductors and equipment, and processes for their production generally have been denied to Communist countries through the operation of the international COCOM embargo, has severely constrained the growth of technology and output in East Europe. The alternative source of supply -- the USSR -- has proved similarly unproductive. Purchase requests to the USSR have been marked by: prolonged delays in delivery (a year or more in many cases), the delivery of extremely poor quality devices, or by no deliveries at all.

East European manufacturers continue to be interested in acquiring both advanced and reliable general purpose devices from the Free World. They would prefer, however, to import the latest semiconductor production

machinery and production licenses in order to escape long-term dependence on Free World sources of supply and to stay abreast of modern technology.

B. USSR

The USSR, because of a deliberate policy of economic self-sufficiency, has not depended on Free World suppliers to meet domestic semiconductor requirements. Imports are generally restricted to small lot purchases of advanced devices. The USSR, however does procure materials processing and production equipment, often at trade fairs, from Japanese and West European firms. Currently, acquisition of US integrated circuit technology and equipment appears to be a priority Soviet target.

C. Illegal Procurement

East Europe and the USSR acquire manufacturing equipment and semiconductor devices through legal, and illegal, channels. No estimate can be made of the amount of illegal trade being carried on, but it is certain that this trade is extremely important to the Communist countries. East Germany, because of its unique position with respect to West Germany, has been (and is) a filter for illegal shipment to other Communist countries. Poland's role as an intermediary in illegal shipments to Communist countries is uncertain although there is some evidence that it has asserted a willingness to obtain equipment for other Communist countries. Trade fairs, at which the latest Free World technology is often displayed, constitute an important illegal source of supply of small numbers of embargoed equipment and devices.