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USSR Seeks to Build Advanced Semiconductor Industry With Embargoed Western Machinery

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USSR SEEKS TO BUILD ADVANCED SEMICONDUCTOR INDUSTRY WITH EMBARGOED WESTERN MACHINERY

CONCLUSIONS

1. The USSR is engaged in a major effort to build a large, modern semiconductor industry using embargoed [redacted] equipment. Moscow will want to use the newly acquired equipment to accelerate development of more advanced military electronics systems where higher reliability, lower weight, smaller volume, and lower power requirements are crucial. Such systems could be used in strategic missiles, space communications and reconnaissance systems, antisubmarine warfare detection systems, and cryptographic equipment.

2. Semiconductors are solid state electronic devices, the most advanced of which are called integrated circuits. These are of major importance in improving advanced weapons systems and sophisticated industrial processes. Current Soviet production is less than 2% of the US level in volume and even further behind in state-of-the-art. Most Soviet military electronic systems are still based on obsolescent transistor or tube technologies, and output of modern third-generation data processing computers is lagging badly behind planned goals.

3. Since 1973, Moscow has purchased about $40 million worth of machinery and equipment for the manufacture of semiconductors, much of it the most advanced available. [redacted] The equipment that Moscow has ordered covers nearly the entire range of processes in an integrated, modern semiconductor industry. The equipment already delivered gives Moscow the capability to produce, at least on a small scale, more complex circuits than currently are in production in the USSR.

4. Although most of the equipment ordered has probably been delivered, US export control authorities have been advised of the Soviet acquisitions and

Note: This publication was prepared by the Office of Economic Research with helpful research from [redacted] the Office of Scientific Intelligence. Comments and queries regarding this publication are welcomed are holding up certain items that are critical to the operation of automated handling and environmental control systems in the manufacture of integrated circuits.

5. The USSR has not yet acquired the manufacturing technology to make effective use of the purchased equipment. In an ambitious scheme to obtain such technology, the Soviets are searching for a West European partner in a joint venture for semiconductor research, development, and production. The partner would hire US experts to train West Europeans who, in turn, would train Soviet engineers and managers. If the USSR acquires all the equipment that has been ordered, and comprehensive manufacturing know-how and training as planned, it may be able to produce hundreds of millions of a diversified mix of ICs annually.

DISCUSSION

Background

6. For many years, the Soviets have purchased, or have attempted to purchase, embargoed semiconductor production machinery.[1] Prior to 1973, however, such purchases were piecemeal and few. Some attempts were made to purchase complete integrated circuit (IC) lines or IC plants outside legal channels, but we do not believe that they were successful. Generally, the Soviets did not acquire or even seek associated "know-how" – the special processing techniques needed to effectively use Western-made equipment – and relied instead on their own installation, maintenance, repair, and operator training.[2]

7. During these formative years of IC manufacturing, the Soviets seemed determined to make it on their own – to buy some items of crucially needed equipment such as bonders and diffusion furnaces in the West and to copy others (Japanese probe testers) but to use Soviet-made equipment and Soviet technology wherever possible. Thus, most Soviet plants combine a few items of Western equipment with mostly indigenous machinery.

8. The sporadic acquisition of Western equipment, by filling crucial gaps in the production process, probably permitted the USSR to get ICs into production somewhat earlier than would have been possible otherwise. However, we believe

1. Semiconductors are electronic components that generally have replaced vacuum tubes as the basic building blocks of electronic equipment. Major types of semiconductors are transistors, diodes, and, in their most advanced form, integrated circuits.

2. The only known major exception is the case of the Soviet "Zond" probe tester, copied from a Japanese prototype. [redacted]

that the overall impact on Soviet production capabilities was not large. Western equipment alone could not compensate for the deficiencies in Soviet-made equipment, backward production technology, and the almost total lack of quality and environmental control in Soviet plants. By 1973, after about four years of production experience, the Soviets were able to produce only relatively simple small-scale integration (SSI) bipolar devices of poor quality, and yields were low. The gap in semiconductor technology between the USSR and the United States was large and growing, with the United States moving rapidly into the production of high-density devices.

9. We believe that up to 1973 the Soviets were producing mostly simple types of semiconductors (transistors and diodes) based on germanium material; the transition to silicon technology, and to the production of advanced types of devices including integrated circuits based on silicon, had been moving slowly. Thus, the USSR produced only about 10 million ICs in 1972, less than 2% of US output[3] (estimated at more than 700 million units). We believe that the Soviets were able to achieve even this low level of output only through the application of large manpower resources, through the use of inefficient trial and error methods, and with stolen or clandestinely acquired Western designs for devices.

10. The Soviets were unhappy with the lack of progress in IC development and production and in 1973 apparently decided to seek large-scale Western help. V.G. Kolesnikov,[4] First Deputy Minister of the Electronics Industry (MEP), and head of its 2d Main Administration responsible for all semiconductor development and production, toured the United States and Western Europe, met with leading semiconductor developers and producers, and assessed Western state-of-the-art. Kolesnikov's trip apparently signaled the start of a major effort to acquire Western equipment and technology on a systematic scale.

11. In 1973 and 1974 the Soviets began to seek through illegal channels sizable quantities of machinery, including the most advanced available. Moreover, they began to seek complete systems, rather than discrete items of equipment,

3. Soviet IC output probably is still less than 2% that of the United States. In 1974, we estimate that the USSR produced less than 30 million ICs, compared with 1.5 billion in the United States. For additional details of Soviet IC production, and of the Soviet semiconductor industry [redacted]

4. V.G. Kolesnikov rose to power rapidly. He was promoted from Director of the Voronezh Radio Parts Plant – to our knowledge, the first ever to manufacture ICs in the USSR – to First Deputy Minister in less than a year (1971). A recent report, still unconfirmed, states that he is slated to replace A.I. Shokin as Minister of the MEP early in 1946.

and launched an ambitious scheme to obtain "know-how" and training (see paragraph 23). In addition, they initiated efforts to acquire huge plant capacity for the production of silicon. Since 1974 the Soviets have shown a readiness to spend very large sums of money, at least $100 million, for semiconductor production machinery, technological assistance, and a semiconductor materials plant.

Recent Equipment Purchases

12. [redacted] report that the USSR since 1973 has purchased embargoed semiconductor production machinery and equipment valued at about $40 million. About 70% of the purchases have been delivered to date, 16% are in process of delivery, and the remaining 14% are being held up by US authorities who have been made aware of the illicit nature of these orders.

13. The scope of recent purchases is shown in Figure 1, which breaks down semiconductor manufacturing into five major processes – materials preparation, mask-making, device fabrication, assembly, and testing – and 14 major sub-operations. The dollar value of those purchases is shown in the table and Figure 2. It is evident that Moscow is trying to build an entire modern industry from imported equipment. Details of individual transactions are described in the Appendix.

USSR: Value of Soviet Purchases of Embargoed Semiconductor Production Equipment,[1] 1973-75

Manufacturing Operation	Value of Equipment (Million US $)	Share of Total (Percent)	Purchases (Percent)		
			Completed	In Process	Held-Up[2]
Total	41.2	100	70	16	14
Crystal growth[3]	16.3	39	100	....	....
Photolithography[3]	9.9	24	15	69	16
Diffusion[3]	7.7	19	100	....	....
Mask-making	4.6	11	26	....	74
Testing[3]	1.5	4	100	....	....
Epitaxy	1.2	3	42	....	58

1. For details of Soviet purchases and attempted purchases, see Tables A-1 and A-2.
2. By US authorities.
3. Additional sales are expected in 1975; they are not included in this table (see Table A-1).

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14. Recent purchases cover almost entirely two major semiconductor manufacturing processes: mask-making and device fabrication. Together, these processes constitute "front-end" processing – that is, they include the operations required for the actual fabrication of semiconductor elements. The single front-end operation not covered by recent purchases is metallization.[5]

15. The front-end processing capability that has been acquired by the USSR is of extraordinary interest since it could enable the Soviets to move rapidly into at least small-scale production of more advanced, higher density types of circuits than currently are in production.[6]

5. Process of laying down the interconnection paths.

6. The critical factors in producing new types of circuits are making the masks and transferring the new design chemically (photolithography) onto the epitaxial layer.

16. Known orders include equipment for only about half of all the operations involved in semiconductor manufacturing. In particular, recent purchases do not include any equipment for assembly, with the exception of two specialized bonders (see the Appendix, paragraph 9), or for intermediate (probe) testing. These operations normally require large quantities of equipment. For large-scale manufacturing, the Soviets require several hundred conventional bonders of the chip and wire type and a large number of probe testers for use on-line in various stages of the manufacturing process.

Suspected Purchases

17. Moscow may have already filled some of these gaps through earlier acquisition of equipment for metallization, bonding, and probe testing although the evidence is not conclusive.

- Metallization equipment (evaporators) may have been acquired from Switzerland. A firm in Switzerland, which has sold evaporators to Poland and has been pushing sales in other Communist countries as well, has had dealings with the USSR.

- Bonding equipment may have been acquired from the United States through Yugoslavia. The United States authorized the export of 90 bonders to Yugoslavia, which have never been satisfactorily accounted for. Suspicion that some (or all) of these bonders might have been reexported to the USSR arises because: Yugoslavia is known to have signed a trade protocol that calls for the export of semiconductor manufacturing equipment to the USSR; Yugoslavia does not itself manufacture semiconductor production equipment; and Yugoslavia is known to have diverted some US electronics equipment to the USSR.

- Finally, the USSR may now be serially producing its own probe testers [redacted] However, that technology is now obsolete and, unless up-dated by the Soviets or aided by follow-on technology [redacted] may still be inadequate for modern high-productivity semiconductor production.

Attempted Purchases

18. Currently, the USSR is attempting to acquire equipment and technology for the entire materials preparation process. Negotiations are under way [redacted]

[redacted] for a turn-key plant to produce polycrystalline silicon with minimum capacity of 400 metric tons per year. The plant also is to produce monocrystalline silicon in unspecified quantities. The projected output of polycrystalline silicon would be equivalent to at least 200 tons of silicon starting material.[7]

19. At present, silicon production in the USSR is small. Hard evidence suggests that the total amount of monocrystalline silicon presently available from domestic sources for the production of semiconductors is on the order of 17 tons annually. By comparion, US consumption of monocrystalline silicon in 1974 was about 360 tons.

20. In addition, the Soviets are attempting to buy slicers for the silicon production process from the United States through normal export channels. Two US firms recently requested authorization from the Department of Commerce to export a total of 90 slicing machines valued at $2.7 million. That number of slicers would be more than adequate to slice 200 tons of monocrystalline silicon per year.

21. It thus appears that every major semiconductor operation except one (scribing) is covered by an actual purchase, a suspected purchase, or an attempted purchase (see Figure 1).

22. Beyond acquiring equipment for particular processes, the USSR has not yet acquired the "know-how" to tie the various operations and processes together in an efficient manner.

Manufacturing Technology (Know-How)

23. The Soviets are going to unusual lengths to obtain IC production technology. They would like to set up a joint production venture in a non-COCOM country to circumvent embargo controls on technology; the Soviets have mentioned Sweden, Austria, and Switzerland. Moscow would underwrite the cost of building an R&D and pilot production facility costing $30 to $40 million. The Soviets hope that within five years the plant would have a capability to develop and produce across the whole spectrum of semiconductor and IC devices, including some military devices.[8]

7. Roughly two tons of polycrystalline silicon yield one ton of monocrystalline silicon.

8. Specifically, the plant would be able to produce large-scale integration metal-oxide semiconductors (LSI/MOS) (P-channel), LSI/CMOS, light-emitting diodes, liquid-crystal displays, bipolar ICs, bipolar discretes, MOS (N-channel) discretes and LSI, silicon-on-sapphire, and power devices.

24. The West European partner in the venture would hire US experts to manage the facility and to train West European engineers and technicians; these, in turn, would train Soviet engineers and managers, presumably in the USSR. Discussions are now going on with two or more firms, [redacted]

25. The USSR also is seeking to acquire manufacturing technology from COCOM member countries in a much more limited and less systematic way through student exchanges[9] and visits to industrial facilities. Although student exchanges are not new, the USSR has been steadily increasing its emphasis on research in the United States on semiconductors. During the past two years, visits of Soviet specialists have expanded greatly under S&T agreements with private firms in the West; these visits have been used to learn about Western manufacturing processses and also to promote the sale of technology from the West to the USSR. For example, [redacted] the Soviets broached the question of buying a complete plant for the production of LSI devices.

Origin

26. The largest share of Soviet equipment purchases - about two-thirds by value – [redacted] are mainly diffusion furnaces, crystal growth equipment, and testers for advanced types of ICs. This equipment apparently was shipped directly [redacted] to the USSR.

27. About one-third of the equipment is of US origin and has been ordered by third parties in Western Europe. Often the third party is a legitimate West European firm acting on behalf of a dummy West European corporation set up specifically to carry out illicit purchases of semiconductor production machinery in the West for the USSR. Dummy corporations exist in several West European countries, most of them directed by the same officials. In some cases, US goods are shipped directly to the legitimate West European firm, routed on to the dummy corporation, and transshipped from there to the USSR. In other cases, US goods are shipped successively to several locations and then recrated and remarked to create the appearance of a legitimate shipment to the USSR. It is not known whether US suppliers are witting of the Soviet connection.

28. The United States is supplying all of the equipment for the mask-making process and for two major manufacturing operations – epitaxy and

9. Most Soviet S&T students in the United States are experienced professionals, rather than students in the strict meaning of the term.

photolithography. Some of the equipment for each of these areas has already been shipped. That which is being held up includes more than two-thirds (in units) of the mask-making machines, nearly all of the epitaxy equipment (10 out of 13 units), and a large amount of photolithography equipment. The potential significance of equipment being held up is discussed below (see paragraph 31).

Potential Impact of Equipment Purchases on Production

29. With equipment already delivered, the Soviets could achieve at least moderate increases in output and product mix early in the Tenth Five-Year Plan period (1976-80). However, we expect the Soviets to have difficulty getting any large amount of new capacity activated because of stringent environmental requirements, lack of production experience in the use of advanced Western equipment, and shortages of qualified personnel

30. If the USSR acquires all the equipment that has been ordered, plus manufacturing know-how and training, it may be able to produce a diversified mix of IC devices on the order of hundreds of millions of units annually, including many advanced types of ICs that are now produced only in small lots or not at all. This capability would elevate the USSR to the status of a major world producer of ICs, trailing only Japan and the United States.

31. The Soviets apparently are planning to establish nine complete manufacturing lines for ICs.[10] They may be limited to only two lines, however, unless all of the equipment now being held up in the United States is received. A critical bottleneck will arise in the chemical processing phase of the photolithographic process for which the USSR has only two of the ten systems ordered. Indeed, if the chemical systems are not shipped, the Soviets probably will be unable to use most of the automated handling systems purchased for the photolithographic process, since the systems are designed to be complementary.

32. If Moscow can acquire the needed complementary equipment, the nine lines would have the theoretical capacity to produce up to one billion simple – low-density (SSIs) – ICs of Soviet design annually,[11] more than 30 times current Soviet output. Although the USSR will want to produce large quantities of simple types of SSI ICs, because such devices can satisfy most of their current design

10. Based on the quantity of photolithographic equipment that has been purchased.

11. Assuming operations 5 days a week on two shifts (16 hours) at the minimum rate of throughput capacity specified by the Soviets and a 20% yield of usable product.

requirements, we believe they also will want to expand the product mix to include both medium-density (MSIs) and high-density (LSIs) devices. The purchased equipment is capable of producing many of the most advanced types of ICs now in production in the West, but Soviet capabilities will be limited by the state of their manufacturing technology. Without Western technology, the Soviets probably will be limited to the production of medium-density devices of the bipolar type, linear circuits, and the least complex types of high-density MOS circuits.

33. Ultimately, the output of ICs that can be achieved using the purchased equipment will depend on the product mix and on efficient equipment utilization. Both productivity and yields can be expected to fall as the mix shifts toward higher density devices. Efficient utilization will require proper installation, operation, maintenance, and integration of the equipment throughout the entire production process.

34. By the 1980s the Soviets apparently are hoping to build a capability in IC production capacity and technology approaching the current US level. Achievement of this goal will depend on Soviet success in acquiring Western technical assistance of the type envisioned in the proposed joint venture in a non-COCOM country. The long-range goal may also depend on Soviet success in acquiring 400-ton capacity for polycrystalline silicon production. Such large capacity would take 6 to 7 years to install. The long lead times for the acquisition of know-how and the installation of silicon capacity make it unlikely that the USSR can reach current US levels of semiconductor output before the mid-1980s at the earliest.

Some Implications

35. Moscow can be expected to attach the highest priority to the use of ICs in the production of military electronics equipment. According to knowledgeable sources, 70% to 90% of the ICs produced in the USSR in past years, including all of the best circuits, have been delivered to producers of military equipment. Even so, most Soviet military electronics systems still use transistor or tube technology and are in need of modernization.

36. The Soviets could choose to use newly developed ICs in future strategic missile systems. The use of ICs makes possible a more complex guidance system, a more powerful computer, and improved reliability while reducing the size and weight of the entire electronics package. In the United States, the development

of a complex guidance system based on ICs has made an important contribution to increasing the accuracy of Minuteman II and to the introduction of MIRVs on Minuteman III.

37. However, ICs in these applications have special requirements such as hardening against radiation. Although purchased equipment can be used to produce even these ICs, unconventional processing techniques and specialized know-how also would be needed.

38. Purchased equipment also is capable of producing ICs that will meet a wide range of other military requirements. These include: most ground support equipment, tactical weapons such as antiaircraft and antitank missiles, artillery fire control systems, and most communications systems for aircraft.

39. The Soviets can be expected to place strong emphasis on the development of complex MOS/LSI circuits for microprocessors. In the United States, microprocessors are now being designed into a wide variety of US military hardware, including airborne inertial guidance, antisubmarine warfare systems, and airborne radars with a look-down capability.

40. In the civil sector, the USSR urgently requires modern ICs to improve its ailing computer industry. Although some third-generation RYAD family computers are now in serial production, output is far behind plan, and advanced models in the family, which require advanced types of ICs, still are apparently in the prototype stage.[12] We believe that the USSR would want to use some of the capability of imported Western equipment and technology to satisfy the requirements of the computer industry. This could be done without jeopardizing support of military requirements only if the Soviets succeed in activating several new IC production lines. Probably two lines would be needed to meet all current and projected IC requirements for civilian computer and computer peripheral programs during the next 5 years.

41. In addition, the USSR hopes to use ICs to modernize other types of equipment for industry and commerce, including especially, communications apparatus, electronic instruments, and numerical controllers for machine tools. Output of IC-based electronic instruments and numerical controllers, in particular, is to be pushed vigorously during 1976-80. According to recently published plan

12. Especially the ES-1050 and ES-1060, which are designed to use fast, reliable emitter-coupled logic circuits.

directives, "automatic equipment with small-dimension (i.e., ICs) electronic digital program control is to develop at an accelerated rate"; and "new forms of instruments based on the wide utilization of microelectronics (i.e., ICs) are to be developed and produced."

42. The USSR also may wish to use ICs in watches and cameras now exported to the West to earn foreign exchange. The growing use of ICs in Western electronic watches and cameras will tend to make Soviet products noncompetitive unless they incorporate modern IC design. Other lesser priority areas of civil electronics production that could use ICs to produce better, more reliable products at lower cost include consumer products produced in high volume for the domestic market (radios and television receivers) and hand-held calculators. Production of hand-held calculators based on complex IC technology could appear to the Soviets an effective way of improving the efficiency of their vast army of planners and managers and perhaps as another way of earning foreign exchange.

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APPENDIX

DESCRIPTION OF EQUIPMENT TRANSACTIONS

Crystal Growth

1. During 1973 and 1974, the Soviets purchased [redacted] two models of machines for growing semiconductor crystals [redacted] – a crystal puller, described as an "optoelectronic single crystal pulling machine"; [redacted] – a float zone crystal growth furnace.[2] There are indications that additional sales of [redacted] pullers and [redacted] float-zone units – may have taken place in 1975.

2. Tentatively, we surmise that float-zone models will be used to produce silicon and that the optoelectronic pullers will be used to produce other types of semiconductor raw materials for specialized applications, such as solid state displays, microwave diodes, infrared detectors, lasers, etc.

Photolithography

3. Orders for photolithographic equipment valued at $9.9 million and representing 24% of the total value of known purchases include: [redacted] mask alignment systems, [redacted] electrochemical processing lines, and [redacted] automated handling and quality (environmental) control systems. Most of this equipment is being supplied by two US firms. An estimated [redacted] mask-alignment systems, of US origin, have been shipped [redacted] expected to sell an additional [redacted] mask-alignment systems in 1975.

4. The automated handling and environmental control systems were scheduled for delivery in the fall of 1975. We do not know if that schedule has been met. These complex systems could be particularly advantageous for the USSR since they are designed to minimize human error and eliminate contamination in the work environment, factors which, in the USSR, are major contributory causes of low yields and poor quality. A West European firm apparently has contracted to assist the Soviets in putting the equipment into operation.

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1. These equipments are used to form monocrystalline ingots of very high purity. The ingot is sliced into wafers which, after being lapped and polished, are processed into actual devices – transistors, diodes, and ICs.

2. The two methods commonly used to produce single crystal semiconductor materials are: float-zone and CZOCHRALSKI.

Diffusion

5. The Soviets have purchased [redacted] diffusion furnaces[3] [redacted]-[redacted] units in 1973 and [redacted] in 1974. The same firm expected to sell the Soviets an additional [redacted] furnaces in 1975. Technical data on model [redacted] furnace is not available. We assume, based on the known characteristics of other equipment that has been ordered, that it is a multitube furnace capable of processing wafers of up to three-inch diameter. Three-inch wafer processing furnaces, in use in the United States since about 1972, are larger than most now produced in the USSR. The Soviets have only recently described one furnace capable of handling wafers larger than two inches.

Mask-Making

6. Orders for the mask-making process include [redacted] *generators* and [redacted] *compilers* to create the art work or basic circuit patterns; [redacted] *plotters* to trace out the pattern of the mask; and [redacted] photo repeaters (step and repeat cameras) to reproduce the master patterns in miniature. These purchases, which amount to about $5 million, represent a large and diversified mask-making capability. For example, a single pattern generator of the type ordered is sufficient to support the output of integrated circuits of a medium-size plant[4]; [redacted] pattern generators would provide a mask-making capacity equivalent to any of the largest US semiconductor manufacturers. The photo repeaters that have been ordered – two different models representing similar levels of high precision[5] – will permit the USSR to handle circuit designs of the highest complexity (LSIs).

Testing

7. Testers purchased [redacted] are designed for final test of high-density (LSI) devices. [redacted] testers have been delivered to a semiconductor plant in Voronezh [redacted] March and [redacted] in August 1975 [redacted] testers were delivered to unidentified facilities

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3. Diffusion furnaces are a crucial part of the semiconductor fabrication process. Following each masking sequence (photolithography), wafers are placed in a diffusion furnace for selective doping of impurities to form the basic device elements (transistors, diodes, etc.).
4. A medium-size plant, by US standards, would employ about 2,000 people and produce about 50 million general-purpose ICs annually.
5. The higher the precision the greater the complexity of circuit designs that can be reproduced.

[redacted]

in 1973, and [redacted] unit was delivered in 1974. The [redacted] expects to sell [redacted] more [redacted] systems to the USSR in 1975. In the case of the [redacted] engineers trained Soviet engineers in the operation of the testers at Voronezh and provided training for associated computer software and equipment maintenance [redacted]

Epitaxy

8. The Soviets have ordered [redacted]pitaxial growth systems[8] in at least six different models, valued at about $1.2 million. One model, we know, is designed for use with gallium arsenide – a material used, among other things, for the production of advanced microwave devices for predominantly military use. It is possible that some of the other models also are intended for growing other exotic materials for special application devices. However, technical data that would permit us to define further the capabilities and functions of these models are not available.

Other

9. In addition, the Soviets have purchased, and received, two advanced types of bonders. The bonders are of an unconventional beam-lead type normally used for limited processing of special application devices and military devices.

8. Epitaxial growth machines are used to grow a second layer of semiconductor material onto a semiconductor substrate. Device elements – transistors, diodes, resistors, and capacitors – are fabricated (diffused) into this layer.

Table A-2

USSR: Attempts to Purchase Semiconductor Production Machinery, 1975

Manufacturing Process/ Operation	Item	Country of Origin	Remarks
Materials preparation			
Crystal growth	Silicon turn-key plant	or	Plant capacity: 400-600 tons of polycrystalline silico
Slicing	Slicing machines	United States	Export request by US firms under review.
Polishing and lapping	Polishing machines Lapping machines	United States United States	Includes fixtures, polishing materials and a 3-year supply of spare parts.
Assembly			
Bonding	Technology: Automatic bonding	United States	An advanced system known by the acronym "minimod"
Encapsulation Ceramic substrates and packaging	Turn-key plant	United States	

Table A-1

USSR: Purchases of Embargoed Semiconductor Production Equipment, 1973-75

Manufacturing Process and Item	[redacted]	Value (Million US $)	Country of Origin	Delivered	Comments
Materials preparation					
Crystal growth					
Pullers		9.2	[redacted]	1973	
Pullers		7.1		1974	
Pullers		8.5		1975	Expected sales.
Mask-making					
Photoreduction					
Photo repeaters		0.3	United States	Sep 1974	
Photo repeaters		N.A.	United States	....	Held up by Department of Commerce.
Photogeneration					
Pattern generators		0.6	United States	Sep 1974, Jan and May 1975	
Pattern generators		N.A.	United States	....	Held up by Department of Commerce.
Pattern compilers		0.2	United States	Jun 1975	
Pattern compilers		N.A.	United States	....	Held up by Department of Commerce.
Plotters					
Digital plotters		Negl.	United States	Apr 1975	
Digital plotters		N.A.	United States	N.A.	
Fabrication					
Epitaxy					
Reactors		0.5	United States	1974/75	
Reactors		0.7	United States	....	Held up by Department of Commerce.
Photolithography					
Mask alignment		0.3	United States	1973	US [redacted]ment re-exported [redacted]
Mask alignment		0.7	[redacted]	1975	[redacted] sales.
Mask alignment		0.9	United States	1975	
Mask alignment		0.5	United States	....	Held up by Department of Commerce.
Electro-chemical lines		0.3	United States	Jul 1975	
Electro-chemical lines		1.1	United States	....	Held up by Department of Commerce.
Automated handling and quality control lines		6.8	United States	N.A.	In process of delivery.
Diffusion					
Furnaces		4.7	[redacted]	1973	
Furnaces		3.0		1974	
Furnaces		3.7		1975	Expected sales.
Assembly					
Bonding					
Bonders (beam lead)		Negl.	United States	1974 and 1975	
Test					
Testers (LSI)		0.7	[redacted]	1973	
Testers (LSI)		0.3		1974	
Testers (LSI)		0.5		1975	
Testers (LSI)		1.4		1975	Expected sales.

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