TECHNOLOGICAL DEVELOPMENT IN CHINA VIEWED THROUGH THE ELECTRONICS INDUSTRY: AN ENGINEER'S VIEW*

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I. MEASUREMENT OF TECHNOLOGICAL DEVELOPMENT IN CHINA

SEVERAL METHODS MIGHT be suggested for examining the level of technology of a country. We might, for instance, seek a vantage point using economic theory or one dependent on natural science and engineering. From the viewpoint of economic theory, factors which promote productive power through a combination of elements of production can be singled out to indicate the level of technology. Specifically we would be using those factors which regulate the interrelation between the elements of production and the production volume. From the viewpoint of natural science or engineering on the other hand, the level of technology can be determined in relation to such factors as the performance of the products (speed, efficiency, strength, durability, etc.), the operation efficiency of factories, the unit consumption of raw materials, and other engineering units. The technological level from this latter viewpoint is mainly provided by an overall combination of design technology, materials technology, and operation technology.

First we shall investigate the technological level as a factor regulating the relationship between the elements of production and the production volume. The so-called production function is a representative means of expressing this relationship in a numerical manner. Here we shall call the production volume Q, the capital volume K, and the labor force L, and postulate the following equation as the relation among the three factors.

$$Q(t) = A(t)K(t)^{\alpha}L(t)^{\beta} .$$

$Q(t)$ is the production volume at time t.
$A(t)$ is the technology coefficient at time t.

* In this article, I did not footnote each source individually. Books and periodicals referred to are as follows: *Chūgoku sangyō bōeki sōran* [General view on the Chinese industry and trade] (Tokyo: Ajia tsūshin-sha, 1963); "Chūgoku no gijutsu" [Technology of China], Inner Circular (Tokyo: Institute of Developing Economies, 1967); *Ajia tsūshin* (Tokyo: Ajia tsūshin-sha, published daily from 1950 to 1966); *Chūgoku tsūshin sekai nyūsu* (Tokyo: Chūgoku tsūshin-sha, published daily from March 1967); *Nitchū kikai bōeki kyōgikai kaihō* (Tokyo: Nitchū kikai bōeki kyōgikai, published weekly from December 1969); *Chūgoku kōgyō nyūsu* (Tokyo: Shinten-sha, published weekly from January 1970); *Kikai kōgyō kaigai jōhō*, July 1971.

$K(t)$ is the capital volume at time t.
$L(t)$ is the labor force at time t.
α is the marginal productivity of capital.
β is the marginal productivity of labor.

With this formulation, even if equal inputs of capital and labor are assumed, the production volume will change in proportion to changes in the coefficient A. Such a coefficient is termed the technology coefficient, and the dimension of this coefficient provides the technological level from the economic viewpoint. Using this method we are able to measure a technology coefficient in actuality.

Further, differentiating t we get the following equation:

$$\frac{\Delta Q}{Q} = \frac{\Delta A}{A} + \alpha\frac{\Delta K}{K} + \beta\frac{\Delta L}{L} .$$

This equation provides us with the increase rate of the production volume, that is, a growth rate summing up the growth rate of capital, the growth rate of labor, and the speed of technological development.

An analysis of China's position in this manner would be quite meaningful. Concrete analysis, however, requires minute examination of such national income data as the volume of industrial production, national wealth (capital stock), the labor force, the marginal productivity of labor and capital, and so forth. And in China at the present moment, there are many areas where data have not been disclosed, particularly concerning the national wealth. Accordingly, I have worked out some very rough estimates for the data required, and will present these along with certain problems involved.

Reviewing technological development over the first five-year economic plan (1953–57), I estimate that the growth rate of the manufacturing sector was about 18 per cent. Supposing that the labor force during this period increased in proportion to the annual growth rate of the population, the growth rate of labor would be about 3 per cent. It is difficult to work out the growth rate of capital without knowing the exact capital stock figures, but estimating K by assuming that the average capital coefficient stands at $Y/K \fallingdotseq 1$, the growth rate of net investment per year would be about 15 per cent. (Here we are considering the combined investments of the agricultural and manufacturing sectors.) Postulating that the marginal productivity of capital (α) and that of labor (β) are about the same as the values of Japan before World War II, they become 0.25 and 0.75, respectively.

When we insert these values in our equation to calculate the increase rate of the technology coefficient, or the speed of technological development, we get a figure of roughly 12 per cent. But since the growth rate of capital and the marginal productivity of capital seem to be underestimated, we can assume a real rate closer to 10 per cent.

As far as data in the second five-year plan (1958–62) and third five-year plan (1966–70) are concerned, they are very inadequate due to the confused economic development under the influence of the Great Proletarian Cultural Revoltuion.

But as we shall see later, there seems to have been remarkable technological development in the electronic industry, playing a major role in elevating the technological level of China as a whole.

Using the recent data on national income estimated by Professor Ishikawa, technology coefficient for the five years from 1963 to 1968 could be summarized as follows. Assuming the NDP growth rate during this period at 5.6 per cent on the average, and as we did for the first five-year plan, assuming that the growth in manufacturing is about double this rate, manufacturing sector growth comes to some 12 per cent. Likewise, on the assumption that the average capital coefficient was 1, the growth rate of capital was around 19 per cent. The labor force we assume increased by 2 per cent, or about at the same rate as the population growth. Inserting these figures into our equation, the growth rate of the technology coefficient was roughly 6 per cent.

Compared with the increase rate during the first five-year plan, the speed of technological development fell by some 50 per cent. We may explain this by noting that in addition to the low posture from which development began in the first five-year plan, these early years also saw massive infusions of technology into China from the Soviet Union and other East European countries which greatly stimulated technological development. In the latter periods, on the other hand, in many fields China was catching up with current level of technology. Coming on top of this, the slowed inflow of technology with the Sino-Soviet split and the Vietnam War, the effects of the Cultural Revolution, and other factors all contributed to technological development at a slower pace than under the first five-year plan. Still an annual growth rate of 5–6 per cent in technological development is very high compared to other countries. For instance, before World War II an annual growth of technological development exceeding 2 per cent in the United States or Japan was considered a sign of flourishing innovation in technology, and even the slower rate in China is far above this level.

Later we will show that a contributing factor to the quick tempo of technological development in China has been the success scored in the unique Chinese development strategy stressing independent designs based on mass movements. Still we cannot neglect the continued introduction of technology from advanced countries which, even though it is not on the same level as previously, is still contributing indirectly to the development of technology in China. An indication of this is the severe criticism in *Jen min jih pao* in early 1970 of the stand taken by "revisionists" to import know-how on electronics from foreign countries. If we turn this criticism upside down, we can see that up to that time, in some form, substantial foreign technology was still flowing into China. Indeed, if China can maintain for some years to come this high speed of technological development, the time when China has caught up with industrialized countries will come earlier than expected.

So far the analysis of China has been a macroscopic one from the vantage point of economic theory, but now we will attempt analysis on the basis of an engineering viewpoint. We have stated that engineering analysis inquires into the performance of the products (speed, efficiency, strength, durability, etc.), the operation efficiency of factories, and the unit consumption of raw materials as elements which indicate the level of the technology. Further using these indicators in comparative study, we can throw into contrast integral aspects of the overall level of technology. But again such a study would require precise data on technology which just is not available for China. Under the circumstances, we must adopt other means to analyze the situation in China.

We can see that the engineering characteristic factors mentioned earlier are ultimately, in accordance with the nature of the technology, under strong influence from a combination of three elements—design technology, materials technology, and operation technology. For instance, in the case of automobile production technology, the quality of the design technology will greatly affect the performance of the automobiles. Even if the design is good, the quality of the materials used will also figure in the performance of the cars. Further, even if design technology is good with good materials used, the final performance will vary according to the heat treatment of the steel, the operation of the machine tools, and welding machines, etc. In the case of synthetic chemicals, although the ethylene gas may be the same everywhere, the quality of the polyethylene will vary according to the method of operation (the kind of catalizer, temperature, pressure, etc.) and the design of the reactor. Hence, the engineering characteristic factors which indicate the technological level will be controlled by a combination of design technology, materials technology, and operation technology. And thus by making a comparative study on these three elements, we make an overall investigation into the level of technology.

Employing this method in an effort to grasp the comparative technological stance of China, several characteristics present themselves. Our overall thesis is that Chinese technology has been built up over the years from a foundation of basic science to the point where China is now approaching the levels of Western Europe and Japan in theoretical fields. Looking into this generalized statement in greater detail, we find first that design technology in the manufacturing industries has reached a high level. For example, although China originally copied foreign models for steel plants, chemical plants, machine tools, construction machinery, mining machinery, power generation and distribution machinery, communications equipment, and so forth, the country is now able to follow through on its own basic designs.

We may say that to a considerable extent China has accumulated the necessary data on practical designing with a theoretical basis in respect to numerical control machine tools, electronic computers, jet planes, and petrochemical plants, all of which are products at the fore of technological innovation. This situation is demonstrated by the fact that China has announced its adoption of design simulation by computer in such fields as geological survey and bridge construction. Thus if China henceforth proves able to undertake not only basic designing but also practical detail-designing, and if this is matched by progress in materials and operation technology, then China will be able to maintain and further elevate the high level of her technology.

But at present there appear to be some problems in regard to materials and operation technology. For example, in terms of metal materials, the country is lagging behind in the development of high grade cold rolled steel sheets, silicon steel sheets, special steel, and rare metals, forming a major obstacle to the technological development of the machinery industry. And as we shall indicate later, although progress has been rapidly registered over recent years in the development of semiconductors, their quality is not yet high enough. There may be some relation here to the strong criticism raised by *Jen min jih pao* in August 1971 against the error in industrialization of laying too great an emphasis on electronics. That is to say, the paper pointed out that electronics is a wide-range assembling industry of a high processing nature and that it cannot develop without the development of such basic industries as metallurgy and chemicals. In this we can see that China itself is taking note of the importance of materials technology in technological development.

Other problems might be noted in respect to operation technology. It is true that China, even without any aid of foreign technicians, is now capable of quickly perfecting the operation of equipment imported from foreign countries for various purposes. Still, China has not reached to the point where operation achievement and efficiency can surpass the records of other countries. In case of Japan, the technological results sometimes exceeds that of the countries from which some technical assistance was obtained. Although the equipment can now be put to use in full production capacity, China is not yet in a position to achieve remarkable cost-down and to stabilize product quality by means of such tactics of management technology as operation control, quality control, and inventory control by computers. In a sense this is to be expected because China now is more concerned with the expansion of production and the most effective employment of capital. Specifically, China has not opted to move into large-scale mass production but continues to stress the development of small and medium industries with electronics as a prominent example. Ordinarily, electronics is characterized by mass production, in particular as mass production technology is a pre-condition to the quality stabilization and economical production of components. Although unfortunately the data is not available, it would be of great interest to study how China handles this requirement in the small- and medium-scale plants. My own guess would be that use is being made of an intensive labor method whereby extensive manual product inspection is carried out. At any rate it will be necessary for China to make substantial development in the field of operation technology before the levels of Japan and Western Europe are achieved.

In summary, the level of technology in China is still in many respects inferior to those of Western European countries and Japan, but the great potential is there to substantially develop the technology, centering on design technology.

II. TECHNOLOGICAL DEVELOPMENT IN THE ELECTRONICS INDUSTRY

We have mentioned that the speed in China's development of technology shows a high value in contrast to the industrialized countries, but the driving force of such development has varied by industry according to the period of China's economic development. During the first and second five-year plans, the major contribution to technological development came from iron and steel, mining, electric power, and machinery. But since the third plan, technological development has been remarkable in the electronics and chemical industries.

Although *Jen min jih pao* has severely criticized the policy of emphasizing the development of electronics as mentioned earlier, China is now rapidly developing this industry, and as far as technology is concerned the advances being registered are outstripping those of other industries. China, for instance, uses computers in design technology and adopts numerical control in machine tool production as well as process control in chemical plants. By a combination of electronics technology and technology of other fields, China is recording technological progress on an approximately same level with Western European countries and Japan.

Here we shall look at the technological development in Chinese electronics in contrast to, principally, Japan on the basis of three aspects—design technology, materials technology, and operation technology.

A. *Development of Design Technology*

1. *Establishment of wire communications technology and standardization of vacuum tube use (1953–57)*

It is a truism that the development of electronics industry starts with the necessity for communications technology, and China is no exception. Before the country had been liberated, there was almost no foundation for the development of electronics. In the old China, only several plants were assembling vacuum tubes and parts for the production of radios, and these vacuum tubes and parts were imported. It was not until three years after liberation that electronics was established as an industry in China.

By 1952, China had learned to design and produce wireless communication equipment for defense purposes and radio sets as forerunners for communications technology. It is not clear whether China could domestically produce vacuum tubes by this year, but more probably China was dependent on vacuum tubes imported from abroad. The year was characterized by the mass training of design technicians in electric engineering. Industrial schools were established throughout various parts of China, including Peking and Harbin, and courses for electrical engineering were inaugurated with other science courses. In Harbin, the first school in the nation specializing in electric engineering was established. Since primary engineers even in electricity were few until these schools were established, the schools had a large effect on the development of the electronics industry.

With this as the preparatory period, the first five-year economic plan was launched in 1953 with major development planned in the field of electronics. In this period, China domestically started to produce vacuum tubes and large power broadcasting equipment, and expansion in the production of vacuum tube radios followed. The technology of vacuum tubes was standardized on the basis of this expansion, and wire communications technology was inaugurated as a result of the necessity to disseminate the telegraph and telegram.

The production of radio sets in 1957 totaled some 390,000 units. At the beginning, the only radio produced was of a four tube high frequency one-stage amplifying type. But by the end of the first five-year plan, five tube super-heterodyne type radios had been designed and were under production, and this substantially improved the performance of radios in China. The number of radio stations reached fifty-eight in 1958 and it became possible to design 120-kilowatt broadcasting facilities.

China also began the domestic production of radio parts. In 1956, vacuum tubes, capacitors, registers, and other electronic parts were being produced. An electronic tube factory constructed in Peking with Russian aid started production from 1956, and in 1958, daily production at this factory reached 30,000 units. A similar factory was later established in Shanghai. In Shangyen, a factory was established to produce capacitors and vacuum tube sockets.

Meanwhile, the telegraph and telephone network was being greatly improved. In 1958, the network covered some 3,200,000 kilometers, 5.6 times more than at the time of liberation in 1949. Of the total, long distance communication accounted for 720,000 kilometers, 2.5 times more than in 1949. Likewise, the city telephone network covered 300,000 kilometers, 4 times more than in 1949, and the prefectural telephone network 2,180,000 kilometers, 10 times more than in 1949. We can see that considerable improvement was made in the medium distance prefectural telephone network. In 1958, the telephone exchange capacity reached 1,470,000 circuits. Even in farming villages, 98 per cent of the people's communes in the nation had telephone networks. Wire communications improved both in quantity and quality. In major cities, the number of telephone stations increased. In 1955, the chaotic telephone system in Shanghai inherited from colonial days was streamlined. A unified operation system in all cities was established, adopting telephone numbers of six digits. Connection time for inter-city telephones and international telephones then came to be very short.

There was steady progress in the national production of wire communications equipment with the first wire communications equipment factory completed in Peking in 1957. Soon it became possible for China to design and produce an automatic telephone exchange, whereas before, only the manual magnet type exchange and common battery type exchange were possible. Design technology in carrier equipment also moved forward. In 1958, at a communications equipment factory in Nanking, a Chinese technician designed the apparatus for a long distance twelve channel carrier equipment more compact than the imported one, and now the carrier equipment has been domestically produced.

We can compare the technological development in China over the first five-year plan with earlier development in Japan. As far as radio technology is concerned, Japan started broadcasting in 1925 and established large power broadcasting equipment on a magnitude of 100–150 kilowatts in the period of 1935–38. Overseas telephone service was done by short wave in 1932. China, on the other hand, in the course of the first five-year plan, caught up with a Japan of about 1940, so that at that time China was at a point slightly more than fifteen years behind Japan.

2. *Development of electronic tube technology and establishment of microwave use (1958–62)*

As we have seen, China consolidated vacuum tube technology centering on the radio, and wire communications technology centering on the telegraph and telephone, in the course of the first five-year plan. In the second five-year plan starting in 1958, further progress was made in these fields. Marked progress was noted in the practical application of these technologies. Production of radios increased dramatically and their dissemination was remarkable. In 1960, some 6 million radios are believed to have been in use by the public. The kinds of radios grew also. In 1960, 160 kinds of radios were being produced, and their performance was also substantially improved. Such high quality sets had been designed as three band all wave radio sets, portable radios, radio gramophones, and shock-proof, heat-resistant fishing radios. In addition, with the building up of vacuum tube technology, China moved into the designing and production of short wave appliances such as small wireless communication equipment with a comparatively short communication range (about 60 kilometers) and wireless communication equipment for villages and fishing boats. After 1960, design technology went beyond short wave into ultra-short wave and microwave appliances. The television that China had first successfully designed in 1958 was being produced in 1960 as the eighteen inch Shanghai 104 model. In 1961, the broadcasting network for television grew to twenty-nine stations.

The development of applied technology from short wave to ultra-short wave and microwave was carried out against a background of momentous improvement in the design technology of electronic tubes. For the general purpose vacuum tube, it became possible to design small-sized tubes ranging from the ST tube to the MT tube. At the same time, China successfully designed special type electronic tubes such as high efficiency transmitting tubes, high frequency oscillating tubes, photoelectric tubes, the Braun tube, and the image orthicon. Such special type electronic tubes made applied technology utilizing microwaves feasible. It was at this time that China nationally produced equipment for receiving and transmitting television, defense radar and ship radar appliances, and radio beacons. At the same time, a design technology to apply special type electronic tubes to industrial equipment was also established. China thus could announce the development of the analogue computer, spectrum-scope, oscillograph, Geiger counter, optical pyrometer, ultrasonic-wave equipment, and X-ray equipment.

Meanwhile, rapid strides were being taken in applied wire communications technology. Development was active in the automatization and multiplexation of the telegraph and telephone. As mentioned earlier, in 1958 China produced domestically a long distance twelve channel carrier developed by a Chinese technician. At this period China realized a sixty channel carrier equipment, an important step in multiplex communication. On this basis, telephones in Peking were linked by a complete six digit system in 1961 with a level of automatization higher than 90 per cent. In 1962, trial manufacture of coaxial cables began at a factory in Shanghai, another indication that wire communications technology was in full swing. At this time, probably designs for multiplex communications equipment by microwave were yet to be realized.

One of the most salient aspects of development at this time was the remarkable progress in the design technology for electric measuring appratus. Domestic production of electric measuring apparatus began in 1954 at an electric measuring apparatus factory built in Harbin with the aid of the Soviet Union. By 1960 China had produced at this factory a 0.1 class alternating, and direct current standard electric meter, a single and three phase electric meter and more than a hundred other kinds of measuring apparatus. At the electronic apparatus factory built in Peking in 1957, China produced precision measuring equipment for wireless equipment including a high frequency micro-voltage meter. Frequency measuring apparatus (10 c/s–1,000 kc/s) and high frequency Q meter were further produced at a communications apparatus factory in Nanking as was a high voltage resistance meter at a scientific apparatus factory in Shanghai. As China already was producing Braun tubes by this time, it is conceivable that domestic production of the synchroscope began too. Still, probably the precision of most of these measuring apparatus was below 0.2 class and the frequency range only a few megacycles.

Lastly, let us compare this development progress in the second five-year plan with the record of Japanese development. For television, a technology using microwaves, Japan started test broadcasting in 1951, whereas China began some ten years later. Japan developed the coaxial cable in 1955, while China developed it seven years later in 1962. In Japan, practical use of microwave multiplex communication was first possible in 1954, but in China, 1962, the end of the period, finds the Chinese still developing their studies some ten years behind the Japanese.

3. *Introduction of transistorization and heightened own design capacity (1963–67)*

In this period, Sino-Soviet ideological disputes were intensified, making it very difficult for China to import technology from the Soviet Union and other East European countries. Nevertheless, self-improvement in design capability narrowed the gap between China and the advanced nations.

It may be cited that application of transistors contributed greatly to the development of design technology. The utilization of transistors in radios started around 1963. In 1964, China embarked on mass production of transistor radios. In Shanghai alone, in this year, nine kinds of transistor radios were designed and produced. At the start of production, models called for only three to four transistors, but in the latter half of this year, designs came out employing six to eight transistors in super heterodyne type high quality sets. By successfully designing transistor radios, it can be said that China grasped design technology to produce miniature electronic products. China opted for printed circuits in the circuit design and soon made good progress in minimizing parts. With capacitors for example, the paper capacitor was soon replaced by MP and ceramic capacitors, and again with resistors, the conventional carbon resistor was replaced by the metallic film resistor. Air type variable capacitors were followed by plastic type capacitors, and coils soon embodied a ferrite core. It seems that the transistors developed during this period were only germanium of alloy and drift types. Silicon transistors were still in the stage of study.

Another characteristic of the period was that with the improvement in China's own design capability, products coming out of electronics were diversified. The electron-microscope can be cited as a representative example. The magnification factor of the first model announced in 1965 was 200,000 times and its resolving power of seven angstrom, was on par with the standards in the U.S. and Europe at that time. Other remarkable products included self-recording ultrared ray analysis equipment, a gas-chromatograph, a 1/10,000,000 precision balance, a precision bridge with 5/10,000 precision at 10,000 cycle, a precision revolution meter with 1/10,000 precision for instant measuring, an isotope thickness meter, an ultrasonic thickness meter, an air survey magneto-meter, a scintilation counter, etc.

Clearly, measuring equipment and analysis equipment were greatly improved in quality and precision, but it seems that China did not realize production of such high quality apparatus as the micro analyzer, the micro comparator and the curve tracer. National production of electric measuring equipment for microwaves, necessary for the development of microwave technology, also remained inadequate. China is now intensively importing such equipment as synchroscopes of more than 100 megacycles, mili-wave signal generators, microwave digital frequency meters, microwave sweep generators, and mili-wave dry calorie meters. Plans are to start their domestic production in the next stage of economic development, and the same may be said for measuring equipment for semiconductors.

In making the comparison of the technological level in China at that time with Japan, it is notable that the gap was narrowed to seven or eight years. While China started using transistors in 1963, Japan had begun application some eight years ahead in 1955. Similarly, development of the electron-microscope was nine years behind, and the MP capacitor and metallic film resistor were eight years each.

4. *Development of digital electronics technology and expanded utilization of semiconductors (1968–)*

In spite of the cultural revolution, the electronics industry progressed remarkably in comparison with other industries. In its own announcement, China stressed that the technological development in electronics contributed much to other industries, especially machinery.

The number of electronics factories across the nation grew twentyfold from 1965 before the cultural revolution to the end of 1970. In Peking, the electronics industry announced a twofold increase in semiconductor production from 1968 to 1970, a rapid tempo of expansion. Electronics, standing in the shadow of the cultural revolution, would seemingly be easy to overlook, but the outstanding facts of its development bring it clearly to the fore.

Production expansion on this scale means that electronics enlarged its foundation in terms of manpower as well as technology, and behind this we can discern clear progress in design technology. One of the most remarkable features of this progress was the rapid development of digital technology. China launched into research on the digital computer, the core of digital technology, much more quickly than might have been expected. Already in 1959, China seems to have test-manufactured a Russian design computer of the electronic tube type. Apparently this was a computer of a long word type with a memory of some two thousand words. The calculation mechanism consisted of vacuum tubes and the memory was a ferrite core and magnetic drum.

With this model of Russian design, as a basis, China made a determined effort to catch up with the technological levels of industrialized nations. The effort began to prove fruitful after 1968. Underscoring this, China announced in the fall of 1967 the development of a full-scale transistor computer with a speed of 6,000 calculations per second. It is reported that the computer embodies 10,000 semiconductor elements of thirty-four kinds and a magnetic core of 50,000 pieces. Design technology in computer hardware in China now appears to be approaching the level of industrialized countries.

It seems that also at this time China started full-scale development of software technology. Reports have since come out of computer utilization in many areas such as for geological survey of the famous oil field in Taching, for design calculation of bridges and large dams, for weather forecasting, for astronomical observation, for molecular structure calculation, and for transportation management throughout the country. Demonstrating the major progress in software development, a small artificial satellite was launched in April of 1970. Large or medium-sized computers are indispensable in the control of artificial satellites and the software required is highly sophisticated, so clearly China recorded in this event a meaningful achievement in technology. As proof that advances in hardware technology are not far behind, China announced about the same time the development of a large-scale computer using transistors with a speed of 100,000 calculations per second. Still, if we go by classification standards used in industrialized nations, this computer would fall in the category of a medium-scale computer.

The development of digital technology brought about steady results in other areas of industry. As far as numerical control over machine tools is concerned, the first machine tools with program control probably came out around 1968. It was a turret lathe with program control. Then, in 1970, full-scale development of NC machine tools was achieved. Announcements came out on a large-type NC lathe and a large-type four dimensional NC milling machine. In 1971, China announced the development of a NC non-circular curve gear cutter, cumulating the remarkable development of NC design technology. At present, China has yet to announce the production of a machining center. This may be because emphasis is being placed on precise processing rather than on saving manpower. Whereas NC machine tools help to promote machinery industry automation, process computers play a major part in the promotion of chemical industry automation. With the development of digital technology in China, the country is steadily making progress in this field.

In the fall of 1969, China developed its first process computer for a crude oil refining plant and, according to reports, successfully solved a complicated operation problem which had been deemed impossible by the conventional meter. Sensors and transmitters for process control are also being developed, as indicated by the many reports that the country is succeeding in the design of new products. Digital technology is also moving forward in the field of measuring equipment. In the fall of 1965, China had already developed its first five unit digital voltage meter. Subsequently, digital technology was further applied to measuring equipment. In 1970, China announced the development of a digital frequency meter and a double integrating digital electric meter.

Together with digital technology, the recent period has been characterized by the development of quality semiconductors and their expanded utilization. In the years of the previous period characterized by transistor radio development, wide application was made of transistors in solid state circuit design technology. But with the current period, transistors have been adopted wholescale in electronic appliances as designing has turned to size minimization, and further, silicon semiconductors have been increasingly put to wider application. Extensive use was being made of solid state measuring equipment in 1969 and medical and other equipment were produced in solid state. Unique products were the aspiration equipment and the ultra-violet ray remedy equipment of tarnsistor type. As to the utilization of semiconductors, a silicon control rectifier (SCR) has been applied to electric machinery. In 1970, machine tools, a welding machine, a motor controller, and a SCR inverter controlled by SCR successively appeared. The expanded utilization of the SCR was apparently part of an effort to conserve and efficiently employ electric power, a goal that China has worked hard to achieve. In this same period, by virtue of new developments in materials technology, China successfully developed a planer type silicon transistor, another proof of the steady progress in high quality semiconductors.

Together with the characteristics of this period that we have outlined above, we should not overlook China's continuing self-improvement in design technology. We might note in this respect that China announced in 1969 the development of a Chinese characters high speed telegraph (translation and transmission speed—1,500 characters per minute). This achievement has been highly evaluated as an indication that China not only has caught up with industrialized nations but also has contrived its own electronic machinery suited to the conditions peculiar to China. Other major developments in the field of communications coming out in 1969–70 include a fully automatic telephone exchange capable of automatic recording and automatic charge calculation, the No. 1 Tong fang hong facsimile, color TV, and six channel transistor carrier equipment.

In measuring equipment, China one by one announced the successful development of types of equipment which heretofore had not been possible to produce domestically. Success was first achieved in such products as semiconductor characteristics measuring equipment, high frequency sweep generators, high frequency synchroscopes, digital frequency meters, precision capacitance bridges, precision mutual inducters, and semiconductor magnetic field intensity meters. In synchroscopes the high quality of the technology has been demonstrated by the announced development of a 8,000 megacycles model. As for electronic parts, China announced the successful development of a high frequency porcelain wave-filter, a micro electrolytic condenser, a high voltage condenser of 1 million voltage a micromotor, and a multi-speed meter.

Other general electronic products include an electron-microscope of 400,000 magnifications developed in 1970, a linear electron accelerator, spark erosion equipment, an electronic clock, cross-section X-ray equipment, and an earthquake simulator. At the same time, rapid progress continued in 1969 in the design development of equipment for manufacturing semiconductors such as the hydrogen reduction furnace, the semiconductor diffusion furnace, and metal vacuum evaporation equipment.

The most crucial task facing China in the technological development of electronics is probably catching up with industrialized countries in the development of the integrated circuit. Test designing is now under way. At the Chinese Export Commodities Fair in Canton in the spring of 1971, China exhibited a screen projection type IC welder, showing that the country is now entering into the stage of IC production. In the case of transistor development, China started with application to radios and then steadily expanded application to whole electronic products. In the case of the IC, however, it is assumed that application will be directed to the development of such military equipment as missiles. It will be interesting to observe how China will apply the IC to its non-military goods. This is a crucial area because industrialized countries have moved rapidly forward in IC technology and are now entering into the stage of the large integrated circuit (LSI).

Generally speaking, as far as the Chinese electronics industry at this time is concerned, China seems to have narrowed the gap with Japan in the development and utilization of transistors to five to seven years. But considering two trends in industrialized countries—the maximization of size in computer and software technology and the entry into the LSI stage—there remains a possibility that the gap between China and the industrialized nations could start to grow. Under the circumstances, future progress in the development of Chinese electronics will be followed with great interest.

B. *Development of Materials Technology*

As mentioned earlier, the quality of materials technology influences the overall level of technology, and this applies especially to electronics since so many kinds of materials are used in production. China has not made available technical data throwing light on many areas of materials technology for electronics, but the following is an analysis of the Chinese electronics industry using that data which is available.

Materials development in Chinese electronics may be divided into two general stages, a ten year stage from 1953–63 and an eight year stage starting from 1964. In the first stage, although the performance of foreign electronic products was substantially improving as new materials were developed, China was still obliged to use conventional materials since the country was lagging behind in technological development, thus restricting the quality improvement of electronic products.

Materials for electronic products might be subdivided into metal materials and non-metal materials. As far as metals are concerned, the delay in development behind advanced countries in respect to steel forced, for a time, postponement of size minimization in electronic appliances and rationalization in processing. Silicon steel might be taken as a representative case. Among the advanced nations, with advancing technology in the rolling and heat treatment of silicon steel, the so-called oriented-core cold rolled silicon steel became popular. In China, however, hot rolled silicon steel continued to be used for a long time, restricting the amount that transformers and motors could be cut down in size. Further, hot rolled silicon steel yields poorly in processing and the usage rate of materials is low. A similar situation existed with magnetic alloys. Since magnetic alloys had not been adequately developed in China, speakers and other appliances could not be effectively reduced in size. The quality of nonferrous alloys in spring materials also was poor in China, preventing improvement in the durability of measuring apparatus. As far as metal materials are concerned, the quality is greatly affected by the nature of the metals and the proficiency of such processing technologies as heat treatment and cutting. Apparently, backward processing methods formed a bottleneck in the development of metals in China. Inspection of materials too was inadequate in China without the proper equipment. At this time advanced countries had already adopted the use of X-ray, ultrasonic wave, and fluorescent equipment for this phase of production. Overall, the reason why many electronic products of China at this time were of unusually large size may be in great part attributed to the low technological level in the production of metals.

In non-metal materials too, a considerable lag in the appearance of new materials can be noted. Whereas various plastics came into use among industrialized countries for insulation and casing, China continued to use lumber, paper, rubber, and at best, phenol plastic. Insulation materials affect the performance of many parts including electric wires, cables, motors, transformers, and capacitors, so the lack of adequate insulation proved to be a major stumbling block for electronics development. Semiconductors too were still stopped in the phase of research and for this reason could not be effectively employed.

Not until 1963–64 and after were the bottlenecks in materials development gradually resolved. In metals, silicon steel eventually became possible with the advent of cold rolling technology, and now China has in this respect finally reached the level of industrialized nations. In magnetic materials too, China has in this second stage come up with highly efficient products. This may be exemplified by the reports from China of the successful development of ferrite, essential for the memory of a computer, and barium alloys, important for their strong magnetic intensity. Also in this stage numerous special steels have been developed. In bearing steel, for example, it seems that China has caught up with industrialized nations, and now is even able to produce miniature bearing. National production of this last product, miniature bearing, is felt to be quite significant in so far as it is indispensable in automation apparatus and missile parts. As mentioned earlier, methods of processing and inspection strongly affect the characteristics of the metal material, and one more feature of development in this stage has been important advances in processing and inspection.

With the development of precision casting and powder metallurgy, China has progressed in the utilization of special alloys. Likewise, it is now possible for China to undertake non-cutting metal-working with the development of spark erosion, electrolytic erosion, plasma coating, explosion transformation, spot welding, and horning finish. Such advances have contributed considerably to the diversified application of materials and improvement of their quality. Various kinds of defects inspection equipment have also been developed, making it possible to use X-ray, ultrasonic wave, and fluorescent equipment in inspection.

In terms of non-metal materials of greatest interest is the rapid progress China has made in the utilization of plastics. It was reported that during 1964–65 China developed fluorine plastic, an improved type of polystylene and a new type of epoxy-plastic binder. Starting from this moment, China made major progress in plastics. With the new plastics, it quickly became possible to develop new insulation materials. The development of the 1,000,000 volt capacitor mentioned earlier is one illustration. Another result was that in 1969–70, silicon rubber began to be used in motors. In addition, it seems that China made major developments in such non-organic materials as high purity porcelain and good quality silica glass.

High purity germanium, it seems, was produced nationally from around 1963, leading to the progress in the development of diode and transistors. Likewise, a rapid progress was made in the domestic production of high purity metallic silicon between 1969 and 1970, contributing to the development of SCR and the silicon transistor. Major development was also noted at this time in metal evaporation and other processing techniques indispensable to the production of semiconductors. Production technology for semiconductors, as we will see later, is concerned with purity and yield. One of the interesting questions here is to what extent inherent limits can be lifted in adopting unique small-scale production system.

C. *Development of Operation Technology*

The most salient characteristic of operation technology in electronics is the mass production engineering for microcomponents, especially the assembly system. Since the technology handles tiny products, quality control as well as accuracy play major roles in the technology.

The electronics mass production system in any country usually starts with the production of radios, and China was no exception. From 1953 to 1957, a mass production system for radios was established in China. By 1960 and 1961, China seemed to have attained a fairly firm standard in the technology for radio mass production. During this period, China produced some 1,500,000 radio units, almost that level of Japan in 1953. In 1961, the market price of radios in China decreased by 20–40 per cent, apparently because the country could decrease costs for radio production substantially by mass production system. At this time, only vacuum tube radios were available. But after 1964, all radios were transistorized and mass production of radios using semiconductors was realized.

We must note that mass production in China is quite different from that of industrialized countries. Compared with Japan, the scale of Chinese factories is quite small and medium- and small-scale factories are scattered throughout the country. Therefore, concentrated production is impossible. Belt-conveyor utilization is limited in the layout of factories remaining at the stage of a batch-type line system. Under the circumstances, work specialization is still inadequate in many respects and there are significant lags behind advanced countries in the utilization of compressed-air driving tools and jigs.

China has yet to adopt adequate shapes of materials for mass production techniques, and consequently, application of special-purpose metal working machines is inadequate. Whereas in industrialized countries, for example, coil type cold-rolled silicon steel sheets are produced for use and formed in continuous type presses, and therefore accuracy and yield have gone up, in China the technology and proficiency have yet to move onto this stage.

In view of the current levels of electronics production in China, it will require a large number of skilled workers well-versed in electricity and electronic engineering in order to improve the standards of the production system. For this purpose, China is encouraging students of primary schools and junior high schools to learn practical electronic technology. Nineteen sixty-eight seems to have been the first year in this endeavor. It is reported that in Peking, primary school children have been receiving training for assemblying radios, and further that 160 junior high schools in the capital have experimental factories for the production of semiconductors. Such operation technology, peculiar to China, is also seen in other industries. This is what is called indigenous technology. One major reason why electronic appliances commonly are manufactured under mass production is that this not only reduces the production costs but also facilitates the quality control. When production is carried out at small-scale factories scattered throughout the country, quality control becomes difficult. Moreover, it causes large variation in the quality of products and increases the disqualification rate.

The only way to avert these unfavorable consequences is to improve the quality of the labor force, and it is for this reason that China is promoting specialized education laying emphasis on practical application, as mentioned earlier. Thus, China is engaged in a mass production system of its own. It is felt that recently the country has made major development in quality control. In the electronics and engineering industries, it has been reported that the qualification rate of products has been greatly improved, substantiating the improvement in the technology of quality control.

We have reviewed the assembly technique character for the finished product, but we have yet to take a look at the operation technology in parts production. A good example is the production of semiconductors. The production of semiconductors requires the highest techniques in various parts production, and from around 1963, the technology came to center on the production of germanium semiconductors. Semiconductor technology firstly depends on the quality of semiconductor materials. The development of large capacity transistors and high frequency transistors depends on the purity of germanium, the raw material, and on the surface treatment, etc. From around 1968, large capacity transistors and high frequency transistors were developed in China, illustrating the improvement of operation technology in germanium production. But among advanced nations, the material of semiconductors changed from germanium to silicon. So China too turned toward silicon production. It has been reported that success was recorded in the production of the silicon single crystal in various parts of the country between 1969 to 1970, again demonstrating the great progress made in China's operation technology.

We might note that the production of the silicon single crystal in China was based upon the so-called indigenous technology. In industrialized countries, equipment for this kind of production is usually housed and operated in special dust-proof, air-conditioned factories. But in China, reports are that production goes on in wooden structures with the windows sealed by paper. Also using simple means, China succeeded in the production of hydrogen from liquid ammonia, the reduction gas of a reducing furnace. Simultaneously China has apparently succeeded in maintaining adequate precision in regulating the temperature of the reducing furnace, a crucial phase of the production, by relying on the skill of the workers. In an industrialized nation this phase of production would be fully controlled by automation techniques. But in China, the unique technique to control temperature depends upon a combination of skillful work and mechanical operation. Basically, China has succeeded because of small-scale factories and by sacrificing greatly the yield and, to some extent, quality of products. The Chinese system would be impossible to adopt in large-scale factories.

Finally, I would like to discuss the possibility that China's operation technology in electronics, so far successfully developing under a unique system, may hit a major snag in future. With the development of semiconductor technology and as transistors are replaced by the IC and then the LSI, there is an increasing need for precise automation technology. Increasingly, the process of materials production will resemble that of a chemical plant. At one time, China substantially curtailed the application of indigenous furnace in the iron and steel industry in order to improve quality and the yield of products. A switch was made to a combination of mass production at large, modern factories and small-scale production by indigenous technology for private demand. It may be expected that China will similarly curtail the application of indigenous technology in electronics, using this method for restricted purposes only, to switch to mass production at large plants as is common among the industrialized nations.