Technical Education of the Fujian Ship Management Office and the Transfer of Modern Western Technology to China

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The Fujian Ships Management Office, one of the first of famous modern industrial enterprises in imperial China, was set up in 1866 within the framework of China's "Self-strengthening Movement". The Ship Management Office provided the Chinese people with their first experience of how to master Western technology. Its important achievements were the building of Western-style ships and the training of navigators. In this respect the Fujian Ship Management Office proves an interesting historical case for the study of the transfer of modern Western sciences and technology to China.

1. Extraordinary Measures

In the 1860's, when China started building modern enterprises, the most serious problems the government encountered were shortage of funds and lack of technology. The latter deficiency was even more difficult to solve because Chinese craftsmen were only skilled in building traditional wooden sailing ships; the steamship, invented and developed by Westerners in the nineteenth century, was a entirely new challenge for them. From the middle of the nineteenth century onwards, Chinese shipwrights began to construct small steamers, but their techniques were not up to standard. As a result, it was necessary to train large numbers of Chinese technicians and workers who would be able to master Western technology. Hence, when the Fujian Ships Management Office was set up, it was decided to employ foreign instructors to give the necessary modern technical education.[1] The hiring of foreign specialists was regarded as an extraordinary measure.

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1 Tso Tsung-t'ang, Memorials *Complete Collection of Tso Tsung-t'ang's papers* 18 (June 25, 1866) 1-6.

This training project consisted of the following three parts.[2]

1. The adviser and deputy-adviser, who were hired for the project, were both Frenchmen: Prosper-Marie Giquel (1835-1886) and Paul d'Aiguebelle (1831-1875). These advisers were in charge of recruiting foreign technicians who could assist China in building eleven large and five small ships between 1867 and 1873. These foreign technicians were also to teach Chinese workers and technicians in the new shipyard how to use machines imported from abroad, how to model relevant constructing equipment, how to build ships according to blueprints, and how to navigate ships. According to the contract signed by the Fujian Ship Management Office and Giquel, the initial term of office of Giquel and d'Aiguebelle was five years. Later, Giquel requested Governor-General Shen Baozhen, who was in charge of the shipyard, to permit the contract to commence from 1869, hence the actual term of office stretched to seven years.[3]

2. The Ship Management Office recruited young, strong and skilled craftsmen from the interior of China to learn shipbuilding techniques from the foreign technicians.

3. Schools for professional training were set up, which enrolled students on the basis of examinations, and which employed foreign teachers to give professional instruction in such objects as manufacturing, navigation, engineering and cartography to different classes so as to train China's own scientific and technical personnel.

In 1874 when the contract for the foreign technicians employed by the Fujian Ship Management Office expired, nearly all of them were laid off and returned to their respective countries. From then onwards, ships were built and navigated mainly by Chinese technical personnel. In the early phase, it can be said that the technical education in the Fujian Ship Management Office had a marked effect on the trainees.

2. The Technical Education in the Shipyard and Its Concrete Results

Most of the first group of trainees in the Ship Management Office were recruited from coastal ports such as Ningbo, Shanghai and Guangdong. Some had already received some technical training concerning the navigation or construction of

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2 Tso Tsung-t'ang, Memorials of Governor-General Tso Tsung-t'ang, who was transferred to Shensi and Kansu, *Complete Collection of Tso Tsung-t'ang's papers* 20, 62-68.

3 *Westernization Movement* V, 82.

modern ships on foreign ships or in foreign factories,[4] others were traditional craftsmen.[5] In addition there were casual workers, who mainly performed non-technical labour in various departments of the shipyard, primarily impoverished peasants and craftsmen from Fushou and its surrounding regions. Most of these workers were totally illiterate.[6]

In accordance with the contract they had signed, the foreign technicians gave essential technical education to some 2000 Chinese trainees (and apprentices).[7] Besides training in the basic operation of the relevant construction equipment, the curriculum devoted a lot of attention to the interpretation of design drawings. Giquel repeatedly stressed that the key to successfully building a ship lay not merely in the concrete operational skills, but in drawing the design and in deciding upon the type of ship one wished to build. He was convinced that one's skill and knowledge would remain superficial if one could not master design drawing first. He realized that any advancement on the technical level would be impossible as long as most Chinese workers were illiterate and restricted to working in a narrow field of production. These factors made it difficult for them to think of a ship as a whole[8] consisting of different parts. In each workshop, under production process foreign technicians first taught Chinese workers how to read the design drawings, and then asked their Chinese students to make a model themselves in accordance with specifications in these design drawings. After the model was ready, the foreign technicians would examine it carefully, pointing out one by one the discrepancies between the model and the design drawings, explaining the key points, and drawing attention to relevant details. Having done so, they would ask Chinese workers to improve the model. Once the model was improved, the foreign technicians would examine it again, and give guidance in view of the concrete questions posed. This was done repeatedly until the Chinese workers mastered the relevant techniques.[9] The Ship Management Office set strict examinations in every workshop to encourage the Chinese apprentices to master the techniques.

Let us now briefly focus on the technical education programme in each workshop and look at the results of the training.

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4 *Compendium on the memorials on the Foochou Navy yard* (4) 9, 11; *Westernization Movement* (V) 84; Prosper-Marie Giquel *Foochou Ship Management Office* 11.

5 *Complete Collection of Tso Tsung-t'ang's papers*, correspondence, (8) 62.

6 *The political papers of Shen Pao-chen* (4) 18; *Compendium on the memorials on the Foochou Navy yard* (44) 8.

7 Giquel, Prosper 'The Foochow Arsenal and its Results', *Shanghai Evening Courier* (1874).

8 *Op. cit.*, 18.

9 *Ibid.*, 60.

1. The requirements of the technical education in the model-making workshop were as follows: the apprentices had to learn how to read the whole set of design drawings of a 150-horsepower steam engine in ships and, in addition, master some basic knowledge of physics so that, after their training, the workers would be able to make all the casting moulds needed for a certain type of steam engine, without the help of the foreign technicians.

2. According to the specifications for the technical education in the assembly shop, the apprentices had to master the knowledge of assembling, starting up and repairing a steam engine, and the techniques for operating the lathes, so that the Chinese students would be able to make a 150-horsepower steam engine themselves once the training stage was over.

3. The technical education in the installation workshop required the apprentices to learn the positions and functions of various machines installed on a ship, including the installation procedures themselves. After the training, the Chinese apprentices could install the main engines independently.

4. The technical level of the workers in the ironworks (rolling workshop) was relatively low. They could master ordinary operation techniques after their training, and their boss could roughly interpret the design drawings. In June, 1873, the Chinese workers began to forge two 150-horsepower steam engines on their own, and succeeded in making two crankshafts, the hardest part of engine building.

5. The workers in the foundry were taught how to master casting techniques, including iron casting and steel casting. After September, 1873, when the foreign technicians left, the workers, working independently, forged the castings of two steam engines (one of which was a new type). The quality of the air cylinder, which was the most difficult component to cast, turned out to be completely up to standard.

6. The technical education in the boiler workshop required mastering ordinary techniques of operation, understanding the complete set of design drawings for the boiler, and gaining the relevant knowledge of lofting and piping. After the training stage was over the workers in the lofting hall could draw the whole set of design drawings according to scale, all in accordance with the original design specification. After the departure of the foreign technicians, the Chinese workers produced two sets of boilers used on ships.

7. Also in the construction of a wooden ship, workers had to be capable of reading the design drawings, mastering the lofting, and working according to

the drawings. They soon understood the design drawing, and, in the end, were even able to draw the construction drawings for an entire ship.

8. The fitting workshop was set up to make furniture, cast small pieces, and install auxiliary equipment. In this workshop also the trainees soon mastered the relevant techniques and could read design drawings without difficulty.

9. The workers in the precision instrument workshop were taught to produce finely tuned instruments, to make such as compasses, telescopes, theodolites, barometers, steam pressure gauges and the sights used on naval guns that were most difficult. Even in Europe at that time not many workers had mastered the requisite skills.[10]

At the outset, the Fujian Ship Management Office invited thirty-nine foreign technicians to be in charge of training the Chinese workers in the various workshops.[11] As we have demonstrated, with their help, the Chinese workers mastered advanced modern techniques in shipbuilding in a relatively short time.[12] Hence the Fujian Ship Management Office became an important base for fostering and training China's first generation of modern shipyard workers. By 1874 the Fujian Ship Management Office had at its disposal the same outfit of shipbuilding equipment that could be seen at a Western shipyard.[13] As a matter of fact, contemporary observers at home and abroad considered the Fujian shipyard to be an excellent example of Western technology transfer to China. Yet, it should be pointed out that the technology which was thus transferred was already slightly out of date as it concerned the construction of wooden hulls.

3. The Technical Education in the Ship Management School

As early as the 1860's men of insight in China recognized that the setting up of new-style schools, implementing technical education and fostering modern technology was fundamental to the development of modern enterprises.[14] No sooner had the Fujian Ship Management Office been established in 1866 than it set up schools.

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[10] For the above points, see *Foochou Ship Management Office* 26-29.

[11] Giquel, Prosper 'The Foochow Arsenal and its Results', *Shanghai Evening Courier* (1874).

[12] *Archive of coast defence* (hereafter *HFT*) B, Foochou Shipyard (I) 93; *Westernization Movement* (V) 458. *Notes of navigation of the ship 'tien-fu'*; *Westernization Movement* (VIII).

[13] *Ibid.*

[14] Tso Tsung-t'ang insisted that new-style schools should be "Places where talented persons were educated"; Shen Pao-chen stressed that "the basic importance of the shipyard lay in schools"; Yi Ch'i, Tseng Kuo-fan and Lu Hung-chang stressed again and again that "to set up the office to build ships and to set up the school to teach students" were both of "basic importance to China's self-strengthening" and "the urgent tasks at present".

The schools set up in the shipyard consisted of two parts: the 'Front' School and the 'Back' School. The Front School concentrated on French techniques of naval construction and design (which were considered to be superior at the time). Its French teachers gave lessons in advanced shipbuilding and design techniques. The Back School concentrated on British navigation techniques (which were considered to be in the lead). Its English teachers taught navigation and engineering.

In the Front School, French was the language of instruction, (hence it was called the French Division of the School). The students were taught to understand the structure and function of the steam engine and its parts; designs and models were made according to specifications; drawing up an estimate for building a ship; making the plan of its hull; sketching it out in the moulding hall; and applying scientific knowledge to practical shipbuilding work were all required skills, and this was the aim of the curriculum. In this connection, the following basic courses were offered, in French, to those who specialized in ship construction: arithmetic; elementary algebra; calculus; plane geometry; trigonometry; perspective drawing (geometrical cartography); analytical geometry; elementary physics; and mechanics; in addition to practical courses such as steam engine construction and hull construction. These courses were to be taught for a period of five years. The technical requirements for students of ship design concerned the drawing of various designs needed in the production. Hence, basic courses in French were offered in arithmetic, plane geometry, perspective drawing, calculus, perspective principle, and the construction of 150-horsepower steam engine to propel a ship. In addition to these there were practical courses in drawing the blueprints needed for the manufacture of all the spare parts of the engine. On average it took the students three years to complete these courses. The requirements of the technical education in the class for apprentices were interpreting and drawing of relevant parts/sections of design drawings and the calculation of the volume and weights of all parts of a steam engine. The apprentice class offered courses, in French, in arithmetic, plane geometry, geometrical cartography, elementary algebra, and steam engine structure. To begin with, one and a half hours of teaching was offered after work, then another one hour and a half was set aside every morning for teaching French. These courses were also to be taught for a period of three years or more.

In the 'Back School' all courses were taught in English (hence it was also called the English Division of the School) to students specializing in offshore navigation and the handling (including the operation of cannons) of the various ships built at the shipyard. This curriculum, which took the students about three and a half years to complete, offered courses in arithmetic, elementary algebra,

plane and spherical trigonometry, nautical astronomy, meteorology, theoretical navigation and geography. Then they were put on board a ship in order to practise their skill in navigating ships. The students of engineering had to learn how to master the theoretical and practical knowledge necessary for operating, assembling and repairing steam engines. They followed courses, in English, on arithmetic, geometry, geometrical cartography, design, the principle and structure of steam engines, the operation and maintenance of steam engines, and the operation of the relevant instruments involved. Furthermore, practical courses were given on the assembly of steam engines (80- and 150-horsepower) for use both on land and on board ships.

Naturally, the Fujian Ship Management Office initially relied on employing foreign technical specialists to carry out this technical education of its personnel. Between 1867 and 1874, the Fujian Ship Management Office employed twenty-four foreign teachers, seven of whom specialized in shipbuilding, two in design, five in navigation, one in engine construction. Nine of them taught the apprentice class. Only nine of these foreign teachers were full-time teachers, the others were technicians in the shipyard who taught part-time. Thus, the study of basic theory was well integrated into production practice. All students specializing in shipbuilding in the Front School for example, worked in workshops for several hours every day during the first two years so as to become familiar with the practical work and to gain experience in managing the workers. At a later stage, foreign teachers were also put in charge of courses on the practical uses of various formulae, the gearing of engines and the machine tools, the boiler, and the power components of the steam engine. After finishing the basic theoretical courses, students specializing in navigation at the Back School, had to go to sea and practise navigation. At sea, the foreign teachers also supervised the navigation. Thus the students learned how to plot courses and practice dead reckoning. On the homeward voyage, students navigated themselves in shifts, the teachers only checked their logbooks. In short, practical courses occupied a very important place in the technical education in the Fujian Ship Management School.

In most of the basic courses in the Fujian Ship Management School foreign teaching materials were used directly without translations. The level of the courses was roughly the same as that in Western secondary schools. When the school was first set up, the students had not yet mastered the requisite foreign language, but in addition to teaching the materials orally fortunately the foreign teachers could make use of demonstrations and practical operations to make themselves understood. Thus, with the help of the reference books provided by the Ship Management Office and by sheer hard work students learned to understand some of the necessary and essential words and the terminology of

Western scientific discourse. This was undoubtedly very beneficial to learning more about Western technology.[15] Still the language barrier must have been a formidable stumbling block for many Chinese students if one takes into account that they had no good dictionaries at their disposal.

4. Actual Effect of the Technical Education in the Early Phase

The Fujian Ship Management School enrolled more than 100 students[16] from the coastal areas of Guangdong and Fujian, most of whom were about 15 years old. They were from poor families, but were bright and diligent. They had a fairly rough idea of written Chinese, and some of them knew a smattering of a foreign language. Beginning from the first half of 1868, more than 100 clever youngsters between 15 and 18 years old were enrolled in each workshop. They formed the apprentice class,[17] placed in the Front School. Thus, just after the School was set up, there were more than 300 students in the school (including the apprentice class). Because of the strict examination and elimination system of the school, only half of these students still remained when they graduated in 1874. A close analysis of the graduates will show the actual effect of the technical education of the School in the early phase.

Among those who had specialized in the shipbuilding course there were thirty-nine graduates; twenty reached the level of engineer; seven were capable of managing and leading a workshop in the production process; one had gained competence as a teacher. Another twenty-one students graduated at a later date at their second attempt. There were twenty-four graduates in the design section. They all mastered the practical knowledge of designing steam engines, and were capable of handling the designs supplied by offices. Nine knew how to design wooden-hulled ships, to calculate the size of the hull, to draw the relevant designs, to loft, and direct construction. Seven of these students approached the level of an engineer. There were eighty-seven graduates from the apprentice class, all of whom mastered the basic skills of their specialty and were capable of practical construction according to the design specifications. Fifty-three of them had proven their capacity to hold the post of supervisor, and some even qualified as engineers. By 1874 fourteen students had graduated in navigation. They could navigate not only on the coastal routes but also on the high seas. Three graduates

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[15] Lin Qingyuan *Draft History of the Fujian Ship Management Office* (1986).

[16] *The political papers of Shen Pao-chen* V; *Complete Collection of Tso Tsung-t'ang's papers*, official documents and correspondence (9) 59.

[17] *The political papers of Shen Pao-chen* (4) 6.

held the posts of teachers and translators. Fourteen graduates, who had specialized in engineering, held the post of chief engineer.

To sum up, because the Fujian Shipbuilding Management School employed foreign teachers, enrolled Chinese students and implemented technical education in the early phase of its establishment, European techniques in both shipbuilding and navigation were efficiently transferred to China at an early date.

Moreover, in order to remain up to date with the ongoing research on the latest shipbuilding techniques and in order to take decisive action in training China's technical personnel after the withdrawal of the foreign technicians in 1874, the Fujian Ship Management School selected several groups of graduates to continue their studies in European countries. As early as 1875, when Giquel went back to France to make purchases for the shipyard, the School sent five students along with him to visit France and Britain so as to broaden their knowledge. Beginning in 1877, the Ch'ing dynasty began to send marine engineering students to study in Europe on a regular basis. By 1897, eighty-six students had gone abroad in four groups, no less than seventy-six of whom were from the Fujian Ship Management School. The students split up to study individually in various schools, mines and naval institutions in France, Britain and Germany. After 3-5 years of study, they acquired special skills and knowledge, becoming experts in specific fields of study at the same level of experience as that of the local graduates. Moreover, the range of their specific skill was greatly broadened.

In addition to the educational programme in modern shipbuilding and navigation, described above, other projects were set up to train students in ballistics, nautical mapping, railway, bridge, and river course management, chemistry, law, and language specialties. As these students finished their studies and followed each other back to China, modern Western technology began to be transferred to China by various routes.

5. Conclusion

From 1866 to 1874 the Fujian Ship Management School provided Chinese workers and technicians with a technical education through the employment of foreign technical specialists. As we have shown it did so with remarkable success. As a consequence, China's first generation of industrial workers and technicians was trained in Western science and technology. They not only basically mastered modern techniques for building steamships, and built forty steamships of various kinds (including some warships) during the course of thirty years, but also learned how to navigate modern steamships according to scientific principles of navigation. Later the majority of these students were to become China's backbone

personnel in the construction of railways, in mining and smelting works, and telecommunications. The first few groups of the graduates and the students who were selected from the ranks of these trainees and sent to study abroad not only became one of the important sources of the qualified naval personnel of modern China, but also undertook to train China's own technical ranks after the foreign teachers returned home. Teachers and leaders implemented the technical education of students in the Fujian Ship Management School and various other new-style schools, thereby ensuring the steady transference of modern Western technology to China. By 1911, the Fujian Ship Management School and another ten naval schools had trained 1900 students (including more than one hundred students studying abroad). When they graduated, 933 of these students were specialized in navigational skills, 415 in engineering, 178 in manufacturing, 55 in torpedoes, and 218 in medical matters. Obviously, the early graduates of the Fujian Ship Management School played an important role in the building up of a group of skilled technical personnel.

The history of shipbuilding can be divided into three periods: the period of the wooden sailing ship; the relatively short period of the composite ship; and finally the period of the iron and steel ship. Before the middle of the nineteenth century, ships were made of wood. After the mid-1800's, the primary frame of the hull was made of iron, and composite ships (iron frame and wooden planking) appeared. The first iron ships appeared in the 1860's, and really became established in the 1870's. The era of the steel ship began in 1880 in the West. To begin with, the Fujian Ship Management Office lagged somewhat behind and was still at the stage of building wooden ships (1866-1876). Thus it may be stated that the techniques it learned and imported were not the most modern and were possibly even outdated Western techniques in shipbuilding. The ships it started to build were old fashioned, their horsepower and tonnage inferior to those of Western ships. Thus the Fujian Ship Management Office was not able to keep pace with the development of Western technology, but since it had already built up an army of its own Chinese technical personnel, in 1876 it began itself to build composite ships with iron frames and the wooden planking, and in 1887 steel ships. The first steel ship built by the Fujian Ship Management Office was modeled on a French steel ship, but its horsepower and the thickness of its hull were said to be of superior quality. After large numbers of the foreign employees had returned home, the Fujian Ship Management Office, relying on its own technical personnel, who had received technical education in the early phase, really did have the ability to steadily catch up with modern Western techniques in shipbuilding. However, because of the poor management and the corruption of

the Ch'ing administration, China's modern shipbuilding industry was unable to develop any further.

One of the main lessons that may be learned from the case of the Fujian Ship Management Office is that the training remained limited to technology. The teaching of management skills, i.e. how a modern shipyard should be run, was not part of the curriculum. The transference of modern Western techniques to China suffered constantly from all sorts of disruptions and sabotage due to political factors. The gap between China and advanced countries thus widened even further. Finally Japan, which imported Western technology at about the same time, moved ahead of China.

We may conclude that when a technologically less advanced country wants to introduce modernization from outside, it is not enough to learn modern Western technology by itself. The eventual success of a modernization programme also depends on the study of management skills, and the cultural context from which these are derived. Therein lies the key to the success of the transference of technology. The Fujian Ship Management Office is often cited by Chinese scholars studying *Xiandai-hua* (modernization) as an example of how a hundred years ago Chinese students were quite able to master Western science and technology within a short time. In this paper I hope to have demonstrated that for the eventual success of the project skillful management was equally important.