Development and Integration:

The History of Engineers in the People's Republic of China

(1949-1989)

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Abstract

The engineering profession has made a significant and distinguished contribution to Chinese society over the past century. It is a contribution, however, which has received little attention from historians apart from the lives of a handful of the most notable engineers. This paper intends to remedy the deficiency by providing an overview of engineers' origins and development in China from 1949 to 1989. In this paper, the author attempts to analyze the developmental history of Chinese engineers by combining technology, culture and society to explore the factors affecting the development of engineers in socialist China. By reviewing the literature and empirically investigating biographical and bibliometric data, this dissertation not only demonstrates the development of the Chinese engineering profession, but also reveals characteristics of engineers' education, career patterns and social status from 1949-1989.

This research leads to the following findings, the first being the stages of Chinese engineers' development. In the process of development, Chinese engineers were faced with various difficulties, including systemic factors that hindered innovation, alongside political factors. China witnessed several revolutions and reforms from 1949 to 1989, and Chinese engineers also went through ups and downs in the wave of history. Engineers have been through three stages from 1949-1989: They learned from the Soviet Union in the 1950s, and then started to explore their way out of the predicament through the construction of the Third Line, while suffering the eruption of ideological conflict of the 1960s-1970s, and then renewing and adjusting themselves in terms of engineering knowledge by learning from Western countries in the 1980s. The second finding is the characteristics of Chinese engineers' occupational patterns. Engineers came from working class and peasant origins and rose through the systems of Chinese engineering education and industrial workplaces into positions of responsibility. The occupational characteristics of Chinese engineers will reveal aspects of engineers' education, their career and vocational status, and their organizations and interaction with society.

The work pursues the notion of engineers as a cohesive occupational group, treats individuals and institutions in so far as they contribute to the elaboration of this concept and tries to relate this to the wider context of the PRC in the 20th Century. This study has implications for the contemporary Chinese engineering profession, as it reasseses itself for its future development.

Vorwort

In dem letzten Jahrhundert hat der Beruf Ingenieur, signifikante und einzelartige Beitrage für die chinesische Gesellschaft geleistet. Doch abgesehen von die Lebensgeschichten einer Handvoll meist anerkannten Ingenieur, wurde dieser Beitrag sehr wenig Aufmerksamkeit von den Historikern geschenkt. Dieses Paper hat das Ziel, durch eine Übersicht von dem Ursprung des Ingenieursberufs und der Entwickelung des Berufes in China zwischen 1949 und 1989, die Defizite zu beseitigen. In diesem Paper versucht der Autor die Entwicklungsgeschichte der chinesischen Ingenieure zu analysieren und in der Technologie, Kultur und Gesellschaft nach Faktoren suchen die diese Entwicklung im sozialistischen China beeinflussen. Durch Reviews der Literaturen und empirische Investigation von biographischen und bibliomantischen Daten, stellt diese Dissertation nicht nur die Entwickelung des Ingenieursberuf in China dar, außerdem werden Charakteristik der Ausbildung, Karrierepattern und Sozialstatus der Ingenieure zwischen 1949 und 1989 offenbart.

Die Forschung führte zu folgende Resultate: Als erstes sind die Phasen der Entwickelung der chinesischen Ingenieur. Im Prozess der Entwickelung, stellten sich dem chinesischen Ingenieur unterschiedliche Hürden, wie systematische Faktoren die Innovation gehindert haben, aber auch politische Faktoren. China mehrere Revolutionen und Reformen zwischen 1949 und 1989, und die chinesischen Ingenieur haben auch ihre höhen und tiefen im laufe der Geschichte gehabt. Zwischen 1949 und 1989 sind die Ingenieur drei Phasen durchlaufen: In den 50zigern lernten Sie von der Sowjetischen Union, dann fingen sie an durch die Konstruktion der dritten Linie ihren eigenen weg aus der misslichen Lage zu entdecken. In der 60zigern und 70zigern litten die Ingenieur durch den Ausbruch der ideologischen Konflikte und in den 80zigern erneuerten und korrigierten sie sich durch das lernen von den westlichen Nationen. Das zweite Resultat ist die Charakteristik der chinesischen Ingenieurberufsmuster. Ingenieure kommen aus Arbeiter- und Bauernfamilien, stiegen auf im System der chinesischen Ingenieursausbildung und industrielle Arbeitsplätze und nahmen Positionen der Verantwortung an. Die Berufscharakteristik der chinesischen Ingenieure werden auch Aspekte der Ingenieursausbildung, ihre Karriere, ihr beruflichen Status, ihre Organisationen und ihre Interaktion mit der Gesellschaft aufdecken.

Die Arbeit verfolgt die Vorstellung von den Ingenieuren als einer kohäsiven Berufsgruppe, Individuums und Institutionen in so fern behandelt wie sie der Zusammenarbeit des Konzeptes beitragen und es wird versucht Verbindung zu dem breiten Kontext der PRC im 20. Jahrhundert aufzubauen. Diese Studie hat Implikation für den gegenwertigen chinesischen Ingenieursberuf, da es sich für die zukünftige Entwickelung neu einschätzt.

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Abbreviations

ACFNSS: All-China Federation of Natural Science Societies

CAE: Chinese Academy of Engineering

CAS: Chinese Academy of Sciences

CASS: Chinese Academy of Social Sciences

CAST: Chinese Association for Science and Technology

CCP : Chinese Communist Party

CIE: Chinese Institute of Engineering

CPPCC: Chinese People's Political Consultative Conference

CPSU: Communist Party of the Soviet Union

KMT: Kuomintang, the Nationalist Party

MOST: Ministry of Science and Technology

NDSTC: National Defense Science and Technology Commission

NPC: National People's Congress

NSFC: Natural Science Foundation of China

PRC: People's Republic of China

R&D: Research and Development

S&T: Science & Technology

Chapter 1: Introduction

1.1 Problem definition

Engineering is an occupation that has a long history. Before the 16th century, the term was used to only describe military engineering; afterwards hydraulic engineering was separated from it. Civil engineering also came into being in the 16th century. By the 18th century, civil engineering and construction became two independent sectors. After the Industrial Revolution, reforms of building materials and structures were required through the construction of factories, railways, bridges and so on. Based on the mechanics of materials and structural mechanics, civil engineering changed its situation from one based on traditional experiences. Around the 1750s and 1760s, civil engineering was considered a social occupation in England. John Smith - who designed the Eddystone Lighthouse at the Ärmel Canal in Britain - was the first man to call himself a civil engineer. In 1771, he founded the first civil engineering group in the world, with the hope that engineering could become an occupation accepted by society and have a certain level of professional knowledge which could distinguish engineers from handicraftsmen and entrepreneurs.

In the 18th century, although Britain was considered the first industrial country, it did not pay much attention to the vocational education of engineers. To some extent, the occupation in Britain was developed from a basic level without much help from high society. However, famous engineers in Britain seemed to be not too different to educated practical men. The engineering occupation in Britain was famous for its emphasis on practical training and practical experience, as well as its doubts about theoretical teaching in schools. On the contrary, after the Napoleonic Wars in the 19th century, the governments of European countries tried to catch up with Britain in terms of industrialization. Thus, they pinned their hopes on current and newly built national engineering schools where teachers imparted knowledge about the British Industrial Revolution systematically. In the long run, the strategy was very successful, and engineers from European countries and

America were on an equal footing with British engineers and even better in many fields by the 1870s.

After 1870, disputes on the relationship between engineering education and economic backwardness - such as whether the stagnation and relative decline of the British economy could be attributed to its cultivation of engineers through practice rather than theory - never stopped. However, one thing we must admit was that European countries had benefitted from learning from Britain in their cultivation of engineers, due to the influence of the Industrial Revolution in Britain. Moreover, institutionalized engineering education helped European countries, especially France and Germany, cultivate a large group of engineers and engineering technicians; most engineers had academic degrees. Therefore, during the second wave of the Industrial Revolution, during the latter half of the 19th century until World War I, the new-style engineers who had professional and scientific knowledge played an important role in the course of technological progress, helping European countries and America to catch up with and even gradually surpass Britain economically in the early 20th century. With the further development of technology, the number of engineers increased and the types varied. In addition, engineers developed a close relationship with science. Apart from traditional civil engineers, mechanical engineers and electrical engineers, electronics engineers, information engineers, network engineers and bioengineers gradually emerged in the 20th century and became divided into smaller, more professional types. Engineers played an irreplaceable role in the two Industrial Revolutions. In the first transition, engineers grasped not only scientific knowledge, but also put technological knowledge into operation – because, for them, scientific knowledge created material wealth. Meanwhile, in the Technological Revolution, engineers transformed not only scientific knowledge into technology but also summarized technological knowledge of many kinds and reported it back to researchers of scientific knowledge. Due to the profound research of science, the increasing complexity of technology and the expanding scale of projects, human activity was not only limited to conquering nature. At this stage, engineers played an important role just like scientists. Von Karman, the pioneer of aviation power engineering, once said, “Scientists study the world as it is; engineers create the world that never has been." British botanist and educator Eric Ashby described engineers thusly: "The engineer is the key figure in the material progress of the world. It is his engineering that makes a reality of the potential value of science by translating scientific knowledge into tools, resources, energy and labor to bring them to the service of man. To make contribution of this kind the engineer requires the imagination to visualize the needs of society and to appreciate what is possible as well as the technological and broad social age understanding to bring his vision to reality."[1]

Modern engineering shaped the physical appearance of modern society and has created miracles beyond the imagination of ancient people. During the course of modernization and globalization and in the process of building a modern society, engineers without a doubt played a key role and undeniably won social prestige and a higher social status. Max Weber said that, as an occupation, the significant and valuable knowledge grasped by professional personnel helped them seize power, establish an occupational barrier, and gain autonomy and a higher class position. After the formation of engineering groups and organizations, engineers asked for higher social positions and salaries, and wanted more benefits from corporations and enterprises. The demands of engineers have become a major task of engineering organizations. In Britain, engineers didn't have a very high position in society - until the early 20th century, engineers and applied science personnel were mostly formed of people of a lower social level, a few excellent engineers as well. This situation was mentioned in the book *The Engineer,* where the author Robert Angus Buchanan discussed the efforts made by British engineers to try to gain the status of gentleman.

On the other hand, American engineers had a much higher status. For most of the 19th century, American engineers, especially mechanical engineers, usually came from the middle or upper level of society and most of them could earn a huge sum of money and high social status. Moreover, the gentry often admired people who successfully became engineers by hard work. However, the only way for engineers in enterprises to realize a higher self-value and improve their personal social status and financial situation was to

[1] In Philip Sporn, Foundations of Engineering: Cornell College of Engineering Lectures, Spring 1963 (1964): 22.

obtain a management position.

This was also true for engineers in European countries. For example, German engineers believed that they received unjust treatment in many aspects of their work, including that they could only hold subordinate positions in enterprises and military departments. The consequence was that in the early half of the 20^{th} century engineers accepted the opinion of the technocracy that engineers would be an independent social force.

From the above-mentioned efforts of engineers to improve their self-value, we can see that engineers were once not very clear about their occupational nature and status. However, this situation had never happened with workers, capitalists, scientists and politicians. The editors of *Geschichte des Ingenieurs: Ein Beruf in sechs Jahrtausenden* say that engineering technology was the result of the hopes and creations of human beings, whose participants included scientific researchers studying the material and spiritual principles of the world in order to expand the possibility of engineering technology, managers who decided investment and grasped the core of the enterprise, engineers who designed technological systems for production, workers who put technological schemes into action, salesmen who expanded markets, customers who judged the quality of technological products through their purchasing behavior, and implementers who formulated frameworks for technological development. Engineers played multiple roles in the process. They could be scientific researchers, managers, salesmen, and implementers. Although they did not control engineering technology independently, they were in an indispensable central position.[2] The multiple roles of engineers put them in a strange relationship and position in society, which could easily lead to a dilemma about understanding their real social status and function.

Therefore, although engineers make great contributions to society, their social demands have not received attention and been met. Furthermore, they have not received the social status and prestige they deserve. When it comes to engineers, many people would

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[2] Walter Kaiser,Wolfgang König (Hrsg.). Geschichte des Ingenieurs Ein Beruf in Sechs Jahrtausenden,Müchen Wien,2006：1.

probably think of them as scientists or entrepreneurs. In the population, the number of engineers far surpasses that of scientists and entrepreneurs; while, concerning their social function, the picture is not so clear. However, due to many factors the current situation is that society is not fair in its treatment of entrepreneurs, scientists and engineers. Concerning theoretical research, the significant social role of engineers has been seriously neglected and underestimated; and, concerning social prestige and influence, the nature and significance of engineers isn't fully understood by society, with the social prestige of engineers being badly affected.

Countries that were late to industrialization like China didn't avoid this situation. Utilization policies regarding engineers and technicians, as well as the social status accorded them, have varied considerably during the Chinese Communist regime. In Party jargon, engineers are included under the broad term "higher intellectual". Chinese engineers as a whole have received very little attention from Chinese historians, and even professional engineers have been treated patchily, with little regard to their special skills and aspirations.

In the 1980s, Britain once again had a fierce debate on whether industrialization had declined and on the situation of British engineers. Some said that the problems in this area were rooted in British culture. Renewed interest in cultural impediments to industry, technological education and economic growth was boosted with the publication of Wiener's highly readable argument that literary intellectuals had captured England's educational system to foster an anti-industrial culture in the formative stages of the national educational system.[3]

In fact, Britain was not the only country that witnessed this situation. In China, people could often feel a similar cultural atmosphere. For example, during the second Sino-Japanese War, the students of the engineering college of Zhejiang University demanded the replacement of the dean since he was not well known. The headmaster, meteorologist Zhu Kezhen (竺可桢), was filled with regret and said in his journal that

[3] McCormick, K. Engineers in Japan and Britain: Education, Training and Employment. Routledge, 2013:12.

so-called celebrities were people who published articles in newspapers or magazines; while the real ‘doers’ were seldom known by their countrymen. For instance, although Yongli and Jüda were the two biggest enterprises in China, chemical engineers in the two companies, such as Hou Debang(侯德榜), Fu Erban(傅尔攽)and Sun Xuewu(孙学悟), were seldom known.[4] Traditional cultures like Britain still have an invisible and powerful influence in society. Engineers are not fully valued, and their names are unknown. Even for senior talents, their fame is not as big as that of professors, and the prestige of the Chinese Academy of Engineering is inferior to that of the Academy of Science. In educational concepts, quite a few people think with good conscience that the most talented people should learn science, second-rate talents should learn literature and third-rate talents should learn engineering.[5] In 2002, metallurgical engineer Xu Kuangdi(徐匡迪), head of the Chinese Academy of Engineering said at the academic annual meeting of the Association for Science and Technology: "Today, when Chinese teenagers are asked what they want to do when they grow up, few of them said they wanted to be an engineer, which worries us. In other words, the social significance of engineers is still not understood in China. If the low social prestige of engineers will not be changed and the engineering profession would not become attractive to teenagers, the consequences could be serious."[6]

Studying the history of Chinese engineers can help us to understand the individual phenomena encountered during the development of Chinese engineers in China, including problems between generations of Chinese engineers due to political influence, the lack of freedom to choose their work under the planned economy, the obscurity of labor division between technicians and engineers, the small population of fully qualified engineers in the world's largest pool of engineers, and so on.

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[4] 郭世杰：从科学到工业的开路先锋，杜澄、李伯聪主编；《工程研究》第 1 卷，北京理工大学出版社，2004 年，第 178 页。Guo,Shijie: From science to industry pioneer, in Du Cheng & Li Bocong eds.: Engineering research Vol.1,Beijing: Beijing Institute of Technology Press,2004:178.

[5] 陈昌曙：重视工程、工程技术与工程家，刘则渊、王续琨主编：工程·技术·哲学，大连理工大学出版社，2002 年。Chen,Changshu: Emphasis engineering, technology and treasure engineering elites. Liu Zeyuan &Wang, Xukun ed.: engineering, technology, philosophy. Dalian: Dalian University of Technology Press, 2002:28.

[6] 徐匡迪，2005年9月28日在上海举行的工程科技论坛的发言。Xu,Kuangdi: Speech On the Engineering and Technology Forum, Shanghai. Sep.28.2005.

Many scholars of China have discussed improving the knowledge capacity and quality of engineers, and reforming the management of engineers and engineering education, but they did not have a systematic analysis of the professionalism of Chinese engineers, or study the cultivation of engineers and the interactive relationship between technological development and the changing professional role of engineers. Research into the professional roles of engineers and investigation of their development can, on the one hand, deepen the sociological study of technological subjects, and on the other deepen the study of technology and contribute to the development of technological sociology, expanding and deepening the study of history of engineering.

From a practical perspective, the construction of the nation needs to develop all types of engineers, but occupations with a higher occupational prestige can always attract an enormous amount of talent. This can promote the development of the industry, but also result in a waste of human resources due to personnel backlogs in a particular profession. In contrast, industries which are in a disadvantageous position but essential for economic development are involved in a vicious circle, their development restricted since they cannot attract talent due to their limited professional prestige.

The development of modern engineering technology has had a substantial impact on social status, social roles, and changes in the professional prestige of engineers. On the contrary, the social status and occupational prestige of engineers also affects the development of engineering technology. In the terms of solving the problem of how to improve the quality of the engineering group, too much emphasis was put on internal factors and the function of social factors was neglected. Moreover, research into the social stratification of engineers is also conducive to the reforming of engineering education and can help with the cultivation of potential engineers, which will contribute to improving the quality of the professional group of engineers in China. As Li Bocong (李伯聪) summarized in his article *Few Questions about Engineers*, the issue of social roles and status of engineers is by no means a matter of the personal gains of individuals or small groups; instead, it is a matter of the rise and fall of industry and of whether the engineering group could attract excellent youngsters. We should deeply illuminate social roles and the status of engineers, popularize the idea that engineering innovation is the main battlefield of innovation activities, make engineers receive proper prestige in society as entrepreneurs and scientists, and change the current phenomena of employing engineers with a theoretical research background.[7] In this paper, the author attanpts to analyze the development history of Chinese engineers since the founding of the PRC by combining technology, culture and society and to reveal the development of Chinese engineers. She pursues the notion of engineering as a profession, treats individuals and institutions in so far as they contribute to the elaboration of this concept, and tries to relate this to the wider context of the PRC in 20th Century.

To be more specific, this paper will focus on questions as follows:

1. How did Chinese engineers rebuild and orient themselves after the People's Republic of China was founded?
2. How did Chinese engineers play a significant role in Chinese industrialization progress?
3. What the social status change of Chinese engineers?
4. What is the relationship between engineers and politics?
5. In what ways do they differ from their predecessors as well as their counterparts in the West?

In the following sections, the author first explains the concepts related to engineers, secondly reviews the literature on engineering and engineers, and lastly describes the empirical data and discusses some of the findings and their implications.

1.2 Objectives and settings

1.2.1 Engineering and engineers

Just as the American educator H. J. Noah said, the most far-reaching result of

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[7] 李伯聪：关于工程师的几个问题 - 工程共同体研究之二。自然辩证法通讯，2006年第二期，第51页。Li Bocong: Some Issues about Engineers. Journal of Dialectics of Nature,Vol.28,Sum No 162,No 2,2006:51.

studying a phenomenon seems to identify the definition of a relatively powerful term, despite its many limitations.[8] Differences between Chinese and Western cultures are eventually embodied in language. Considering that the object of the study is a loan word, 'engineer', we need to first distinguish and explain its definition.

The word engineer can be found as early as the eleventh century in a Latin document, with three different ways of writing it: ingeniator, engignor or incignerius, which are derived from the Latin word "ingenium" (thought, sharp mind), used to describe manufacturers specializing in weapons for stronghold attacks. In the late Middle Ages, the word was rapidly integrated into the Roman languages in the form of ingegnere or ingenieur, but they were not used to describe all personnel solving engineering problems. "Ingeniosus artifex" and "magister machinae" were also used to represent excellent craftsmen and professionals manufacturing attacking weapons respectively.[9] The word "engineer" derived from "engineering" refers to creators. The English word engineer refers to a professional practitioner of engineering as a noun, and equates with 'to design' and 'to construct' as a verb. According to China Encyclopedia Dictionary, the English word "engineering" is derived from "engine" or "engineer". In the eighteenth century, the word "engineering" which refers to work of engine optimizers or engineers, was derived from "engineer". We can say that the concept of engineering is closely related to activities of engineers.

As opposed to Western languages, the word "工程" (Gong Cheng) is not a loan word but a compound word of "工"(Gong) and "程" (Cheng). In the ancient Chinese language, "工程" (Gong Cheng) mainly refered to large-scale construction activities, especially in civil matters. This is the earliest meaning of the word in the Chinese language and is also the most common sense of the term in the Tang Dynasty. It was recorded in historical records that the "wood and tile project" of Santai (三台)of the Northern Qi Dynasty was

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[8] Harold J. Noah: Defining Comparative Education: Concepts. Relevant Methods in Comparative Education, 1973:111.

[9] Walter Kaiser,Wolfgang König (Hrsg.). Geschichte des Ingenieurs Ein Beruf in Sechs Jahrtausenden,Müchen Wien,2006：33.

a large-scale civil engineering project which involved 300,000 workers and craftsmen.[10] The difficulty of projects, a high cost of manpower and the difficulty of the examination are probably the main reasons for the appearance of "工程" (Gong Cheng). The term combines the meaning of "工" (Gong) as woodworking tools, the identity of craftsmen, the social division of various works and construction projects and the meaning of "程" (Cheng) as a basis of measurement, standards, progress and examination. It is not difficult to know that the primary meaning and usage of the term is relatively clear since it appeared. In addition, in the ancient Chinese language, the term sometimes refers to a particular concrete work or homework schedule. Therefore, "工程" (Gong Cheng) is not simply a literal translation of the word engineering, but a term with similar meaning in Chinese chosen by scholars. It is worth noting that the Tianjin Northern Western School, founded in 1895, listed "工程" (Gong Cheng) in the five professions and named it as "工程学" (Gong Cheng Xue). That "工程学" (Gong Cheng Xue) was included in the formal education of China indicated "工程" was no longer seen as some kind of activity but the discipline's official name.[11]

The modern definitions of "工程" (Gong Cheng) are different depending on the different characteristics that scholars emphasize. In the Modern Chinese Dictionary, the Chinese Dictionary, the Encyclopedia of Natural Dialectics, Cihai and Encyclopedia Britannica and other reference books, the general concepts of the term in China mainly include subjects such as technical skills, work, construction projects, activities and the production process. According to these books, in the Chinese context, the meaning of engineering can be defined as the process of activities and its results of people transforming and using nature actively with the help of scientific knowledge and practical experience. So, the meaning of engineering between a Chinese context and an English one are consistent.

[10] 北史·列传第六十九"儒林上",Beishi·Liezhuan No.69:Rulin shang. (Northern History· the sixty-ninth of the Biography "the scholars Ⅰ").

[11] 孔寒冰：工程学科 ： 框架、本体与属性。杭州：浙江大学出版社， 2011: 14-15。Kong, Hanbing: Engineering disciplines: framework based on ontology.Hangzhou:Zhejiang University Press.2011:14-15.

However, the ancient Chinese language does not have a word equal to the modern "工程师" (Gong Cheng Shi). Although "匠人营国" (Jiang Ren Ying Guo) has long existed in the Book of Diverse Crafts (考工记)[12]，"工正" (Gong Zheng), "工尹" (Gong Yin),"匠师" (Jiang Shi) and "工师" (Gong Shi) in traditional society can be regarded as the prototype of "工程师". Despite the fact that people participated in and played important roles in engineering activities to some degree, they could not receive relatively high social status and prestige due to their low degree of professionalism. The terms "工师" (Gong Shi), "工程司" (Gong Cheng Si) and "工程师" (Gong Cheng Shi) have coexisted from the late Qing Dynasty to the Republican period. In 1912, when the Chinese Institute of Engineers was founded, there were no doubts about the term "工程师" (Gong Cheng Shi) as an official title of the social role.

In fact, since "工程师" (Gong Cheng Shi) is a term created equal to the word "engineer" according to the similar professional title, the definition of Chinese engineers referred to is totally consistent to that in Western languages. Then, the question of what an engineer is is the most direct object of study in this essay.

So far, the concept of engineer is vague, with no precise definition made with common recognition. Many scholars have tried to define it, for instance The *Oxford Advanced Learner's Dictionary* explains, "an engineer is a person who designs, builds or maintains engines, machines, bridges, railways, mines, etc."; while the *Encyclopedia Britannica* believes that an engineer is the project designer of, for example, houses, streets, drainage systems and other civil engineering designers. The *Modern Chinese Dictionary* defines it as: "A job title for technical cadres of specialized personnel who complete the task of designing a specialized technical design and construction work independently." The editor of *Geschichte des Ingenieurs Ein Beruf in sechs Jahrtausenden* provides a broader definition of engineer: "'Engineers' are those solved demanding technical and organizational tasks in positions of responsibility in the historical times". However, "now in Germany, 'engineer' refers to the

[12] The Book of Diverse Crafts is a part of the so called Rites of Zhou, so it is also called the Rites of Zhou·Book of Diverse Crafts. The Book of Diverse Crafts is an important monograph of artisan craftsmanship during the pre-Qin period, including the experience and scientific conclusion and understanding of some technology, skills and rules in the handicraft industry at that time.

graduates who hold the degree of engineering, that means ‘engineer’ should be defined from the academic level at first.”[13] According to these typical definitions, three key elements can be summarized; the author tries to define “engineer” in a recursive way in this paper as follows:

a. people with skills;

b. people with professional skills;

c. people with professional skills that specialize in engineering activities.

According to *a*, engineers are not people who can only assume resources, but people who must provide services and make a contribution to society. The influence of these people on the environment is first to adapt technology to it and then to have a positive effect on it, which requires obtaining certain knowledge, understanding their relationship with the environment and knowing how to adapt to and to affect it. It requires them to possess certain skills and abilities which can help them know how to adapt to and affect their environment; and requires them to have some personal qualities and to be people who can self-develop in the process of affecting their environment. This is the first-level meaning of what it means to be an engineer.

According to article *b* of the definition, engineers are people occupied in a particular profession. All occupations, professions, and trades are versions of a career “职业” (Zhi Ye). However, the word ‘profession’ is partial to specialized careers while ‘trade’ refers to standard ones. The difference between the two words is mainly in the required educational and training level, the length of the formation process and their social responsibility. Therefore, people with professional skills must accept a complete higher education and specialized professional training and have the capacity and obligation to update and complete their own education and training in their career. On the other hand, they must also accept strict restrictions related to professional work ethics, since their responsibility to society surpasses that to the service sector they are in. The above characteristics are the

[13] Walter Kaiser,Wolfgang König (Hrsg.). Geschichte des Ingenieurs Ein Beruf in Sechs Jahrtausenden,Müchen Wien,2006:1.

second-level meaning of what it means to be an engineer.

According to article *c* of the definition, engineering is a profession different to scientists, doctors, teachers and lawyers in that their professional activities are limited to the engineering field. However, the engineering field is a dynamic category and there are many branches besides the traditional four sub-fields, namely, civil engineering, machinery, electrical engineering and chemical engineering, and new branches are still generating and developing. The educational department and industrial department give a classification of engineers in line with engineering disciplines and engineering products respectively according to their value goals. This eclectic method seems to classify engineers based on their social function and can be regarded as the basis for contact between universities and industries. The recognized functions include research, development, design, manufacturing, operations, experiments, marketing, management, consultation and education. An engineer should be involved in at least three fields; only in this way can we adapt to the modern integration of science, technology and production. Since engineers are people limited to engineering activities, they obtain certain characteristics of engineering, including uniqueness. Engineering activities are practical ones specific to a particular time and place. Due to the irreversible course of time and the uneven "geographic space" (including resource conditions) and "social space" (social environment such as policy, law and cultural environment) of engineering activities, as well as the inevitable effect of changes in the space-time environment and conditions on activity subjects, activity goals, operating environments, boundary conditions, restraining forces, driving forces, methods and approaches, all become activities with unique characteristics. The uniqueness and the characteristics mean that engineers strive for optimization when making engineering decisions. As such, when regarding engineers as research objects, we should not only analyze the conditions of the occupational group in our research, but moreover place engineers in an engineering environment and analyze the history, politics, external environment and status, all of which affect decisions.

Based on this explanation, the formation of engineers has three basic facts: their education, special training and experience of engineering. So in this paper, to understand the formation and development of Chinese engineers, we should focus on these three main points.

1.2.2 The scope of this study

The study puts emphasis on Chinese engineers and chooses Chinese engineers as research objects, taking the following reasons into consideration.

In recent years, issues about engineering philosophy, engineering education and the quality regulation of engineers in China have received widespread attention. When analyzing their domestic status, scholars tend to do comparative analysis and usually choose engineers in France, Germany, Britain and the United States as comparative objects. In analyzing their differences, they compare their education, social background, level of industrialization, occupational status, quality regulation of the occupation, and so on. It is worth noting that these are developed countries with a high degree of industrialization and a complete industrial system and career framework of engineers of their own. However, Chinese engineers could be a new type of engineering profession in the 20th century. The industrialized countries mentioned above which have a high level of industrialization and a complete industrial system are different from China in many aspects, including their place in the world environment, national politics and processes of science and technology. As a latecomer to the development of industry, China has its own characteristics in developing industry, ones worth further investigation and research. However, the study places emphasis on Chinese engineers in the mainland and does not involve the evolutionary process of engineers in Hong Kong, Macao and Taiwan in the second half of the last century.

The other problem is the time range of this study. The time entry points of research on the development of Chinese engineers are different according to different research objects. If the study aims to answer why Chinese engineers came into being very late and why Chinese engineers did not emerge during the transformation of Chinese artisans but were forced to develop through external pressure for the purpose of self-reliance, the research could probably range from the late Qing Dynasty to the early 20th century.

Whereas if the study aims to figure out the differences between Chinese engineers' standards and those of typical engineers in industrialized countries, and how the group awareness of Chinese engineers came into being, the start point is generally located after the establishment of the PRC. In addition, some research into the former history of engineers is necessary, but it must serve to the study on.

The development and expansion of the professional group of engineers benefited from the creation and enforcement of the modern state.[14] The engineering profession has developed in China over a period of about 100 years. In the first half of the century, Chinese engineers were in their infancy and exploration stage and they did not have a chance of developing until the foundation of the PRC, when the Chinese Communist Party (CCP) put forward economic construction centered on heavy industry. Chinese engineers have some occupational characteristics similar to those of other countries; but, at the same time, since the change of China's political environment, they are endowed with a unique developmental route. Influenced by the Soviet Union in the 1950s, Chinese engineers are just as the same as Soviet engineers; in the 1960s when China closed its national door under the slogan of independence, Chinese engineers started to explore their way out of the predicament; in the 1970s, the direct eruption of ideological conflicts put engineers and engineering education into hard times; and in the 1970s, when China opened its door to introduce technology and projects from Western countries and Japan, they relocated and developed again. In only 40 years the vocational education, occupational status, social status and political status of Chinese engineers has gone through several changes. In the development process of China's industrialization, engineers played an essential but seemingly obscure role. The question of why this contradiction came into being is one of problems that the author tries to solve in this study.

In this way, the development of engineering needs a country or a society which is undergoing a process of industrialization and the process of industrialization should be

[14] "Die Entwicklung und Expansion der berufsgruppe der Ingenieure profitierte von der Entstehung und Durchsetzung des modernen staates." Wolfgang König:Vom Staatsdiener zum Industrieangestellten:Die Ingenieure in Frankreich und Deutschland 1750-1945. Walter Kaiser,Wolfgang König (Hrsg.). Geschichte des Ingenieurs Ein Beruf in Sechs Jahrtausenden,Müchen Wien,2006:179

based on the emergence and maturity of the nation. Therefore, the establishment of the PRC is the starting point of the study.

The time range of the development of engineering discussed here is from the 1950s to the late 1980s, nearly 40 years of history. The choice of the time takes the developmental duration of engineers into consideration. According to the statistical analysis on the status of modern Chinese engineers, it is found that the first generational group of Chinese talents who could grasp Western scientific knowledge can be traced back to the 1920s-1930s. Considering the advance from basic scientific research to research on applied engineering technology generally requires a generational effort, the first group of engineering technicians appear from 1945 to 1965, if Chinese engineering technicians finished their study at the average age of 25 (it is noteworthy that engineering technicians here are not general engineers). Therefore, it is possible that some engineering pioneers appeared even earlier. Then, based on the research of Fang Heihu (方黑虎) and Xu Fei (徐飞), of the 480 engineering and technical expert academics the Chinese Academy of Engineering selected as samples, 395 were born between 1920-1940, making up 82.3% of the total number, which indicate that there was a time gap between learning of modern scientific theories from Western countries and the practical application of these engineering technologies.[15] Based on Fang and Xu's investigation, we can know that the effect of the development of engineers on historical events and policy adjustment needs a period of time.

From 1949 to 1989, the author divides the development of Chinese engineers into three stages, the first stage being from 1949 to 1965, whose basic characteristics were the formation of a socialist planned economy and the further improvement of modern industry and the Chinese engineering system. At this stage, capitalists and entrepreneurs were cleared out of the engineering community and the government was the capital owner

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[15] 方黑虎，徐飞：中国现代工程技术专家群体状况研究。科技进步与对策：2003 年 8 月。Fang, Heihu & Fei Xu, Research on the social status of Chinese engineering and technical experts. Technology Progress and Policy: Aug.2008:39-41.

and took the place of entrepreneurs. For political reasons and the international situation, China turned to learn from the Soviet Union instead of Western countries and its engineering educational pattern was changed in the 1950s. At this stage, the completion of the 156 projects assisted by the Soviet Union marked a further upgrade of the macro-engineering system. Engineers who were in an occupational position before 1949 had gone through a significant transformation in politics and occupational status, and the engineering system which took the "Unit" (Danwei: 单位) and "Professional Title (Zhicheng: 职称)" system as evaluation criteria was formed.

The second stage is from 1966 to 1976 - the Cultural Revolution, during which engineers were in their worst situation in terms of living conditions and social treatment. The Great Leap Forward and the political movements of the Cultural Revolution slowed national industrialization, however, the "43 program" (四三方案) in which the construction of 26 projects was another large scale technology import after the 156 project showed a "anti-Cultural Revolution" trend. Moreover, the significant achievements during this period included the "two bombs and one satellite" project (两弹一星计划), which reflected the development of engineering with Chinese characteristics. During the Cultural Revolution, education in engineering was severely damaged and a large number of graduates majoring in engineering disciplines had to go to the countryside in response to the call of the Party. Besides, the shutdown of higher education institutions and the recommended admission system caused incompetent cadres in engineering and technological areas.

The third stage was a transitional phase from a planned economy to a market economy. At this point, China returned to the path of centering on economic construction, and the assertion that science and technology were the primary productive forces, to an unprecedented degree. The disadvantages of engineering education featuring high specialization were increasingly evident and engineering education went towards the path of reform again. Many drawbacks of the planned economy were improved gradually, including the constitution of the engineering community, engineering education patterns and free choice of occupation among engineers. Chinese engineers have both opportunities and challenges. In the structure and the level of modern engineering, China, on the one hand, continues to make up ground in terms of mechanization and electrification; on the other hand, it is catching up in terms of information technology. The development of Chinese engineers went through a formative period by learning from Soviet socialist engineers, the exploration period of finding its own developmental approach and reforming the Soviet pattern, and the reform period since the transformation to the market economy.

Therefore, this paper took in the time between 1949 and 1989 and divided it into three stages, from 1949 to 1965, from 1966 to 1976, and from 1977 to 1989. The influence of the first two phases is the focus of this article, and the third phase focuses on the negative effect of the first two stages.

1.2.3 Concepts related to engineers in a Chinese context

There is a problem with engineering, in the context of China. Chinese communist publications fail to define scientific and technological terms clearly and tend to give Western terms different meanings. For example, generally, in Western countries, graduates of engineering colleges are classified as engineers; but in China graduates of engineering colleges must acquire three to four years of experience as technicians before they are entitled to claim the title of engineer. Additionally, many uneducated but skilled workers are classified as engineers. On the other hand, the broad term engineering technician is used in official reports and party jargon, while the two categories of engineer and technician are not distinguished. Similarly, no distinction is made between scientists and engineers. In addition, there are some titles with political meanings and a special historical background, including scientific and technological workers. That is the reason why some terms in the Chinese context are explained here.

Intellectual is a word that was used most frequently during the class struggle in China. Chinese historian Yu Yingshi (余英时) said: "According to the general understanding of the Western academic circle, so-called intellectuals must deeply care for their country, society, and everything related to public interests in the whole world more than their individual interests (including groups they are in) besides devoting themselves to professional work. So it was said that intellectuals in fact had a religious spirit."[16] Therefore, intellectuals must have two attributes: Aloofness and the ability to intervene; that is to say, intellectuals must maintain a certain distance from society and there must be an independent place which belongs to them only. However, they must concern themselves with and participate in public social affairs, be able to develop and control public opinion in a macroscopic way that surpasses any individual benefit to themselves, and have social consciousness. In general, intellectuals expect that the causes they take on cannot only give full play to their talents and meet their self-interests and value orientation, but also benefit the whole of society, realizing the unity of the subjective and objective.

Intellectuals can be divided into three types: The first are intellectuals who are managers of the ruling circle; the second is the technical intelligentsia such as technical experts; and the third are humanistic intellectuals. In China, intellectuals are a part of the working class and are a group who grasp advanced scientific knowledge and technology. Here intellectual is no longer a word simply synonymous with a certain degree but an occupational title with a certain connotation.

Within intellectuals, there are still different classes and interest groups. Gao Guang argues that Chinese intellectuals can be divided into three parts according to their different social roles and status: (1) intellectuals involved in material production, which mainly refers to engineering and agricultural technicians who are distributed in industrial, agricultural and circulation departments, who generally become technological intellectuals; (2) intellectuals engaged in professional work like cultural education, scientific research and health, including researchers of natural science and social science, as well as teachers in schools at all levels, writers, health care personnel and other specialized business personnel; and (3) intellectuals engaged in social management, including managers who receive professional training and are occupied in the relatively complex mental work of enterprises and public institutions such as national administrative departments and social public affairs

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[16] 余英时：《士与中国文化》 自序，上海人民出版社，1987。Yu, Yingshi: "Scholars and Chinese culture",preface, Shanghai People's Publishing House, 1987:3.

departments.[17] According to these classifications, we can know that due to the characteristics and wide range of the engineering profession, engineers are mainly personnel engaged in the first category as well as parts of the second and third categories. In general the engineers' group is included in Chinese documents where the status of intellectuals after the founding of PRC is mentioned.

The application of *Scientific and technological workers* on the one hand reflects the fact that the Communist Party advocates the idea of professional equality and believes that scientific and technological work is important in modern society. In distinguishing scientific and artistic workers, it is clearly defined that scientific and technological workers are people who grasp the relevant professional knowledge in the natural and scientific field, and are engaged in the research, development, popularization and application of scientific technology as well as people who work in scientific and technological management. Classifying them according to industry, they include engineering and technical personnel, health workers, agricultural technicians, scientific researchers and teaching staff. Scientific and technological workers are major members of the Chinese Association for Science and Technology whose job is to build a united scientific and technological front. Therefore, scientific and technological workers are intellectuals distributed in various industries taking on scientific and technical work.

Scientific and technological talent is a term unique to China; it is not quantitative and has four relevant concepts: Scientific and technological human resources, professional technical personnel, personnel engaged in scientific and technological activities and R&D staff. Concepts of scientific and technological talents are closely related to statistical indicators such as scientific and technological human resources, professional technical personnel, personnel engaged in scientific and technological activities and R&D staff in different levels. The term is mainly used in professional statistical work and can often be seen in unified statements by the state statistics bureau on human resources engaged in scientific

[17] 高光，李真，马鸣，王昌远主编：中国社会主义社会阶级结构和阶级斗争。北京：中共中央党校出版社。1990。Gao,Guang,*et al,* eds.: The class structure and class struggle in socialist society of China .Beijing: Central Party School Press, 1990.10.:94-95.

and technological work to meet the needs of issue analysis, policy research and strategy formulation and implementation regarding people's scientific and technological ability.

For various reasons, the term engineer is scarcely seen in PRC documents in the second half of the 20th century. Instead, terms like intellectual, scientific and technological worker as well as scientific and technological talent can be often seen. Therefore, what we need to do here is to pull out the engineers group from professions with political significance and analyze its characteristics and development models.

1.3 Research approach

1.3.1 Methodology

The research methodology consists of both a literature review as well as empirical investigations. The literature review involves scientific approaches, factual statistics and existing surveys from cases to either corroborate or refute my theoretical hypotheses. Empirical evidence has been drawn from both. The research methods are as follows.

First, a historical analysis, in which the author describes, analyzes and explains the past based on information sourced from materials relevant to the research subjects. The author collects facts related to the occupational development of Chinese engineers and describes, analyzes and explains the evolution of the engineering occupation in China so as to provide the basis for the analysis of Chinese engineers. With the background of the CCP directing scientific and technological policies and affecting social, political and economical development over 40 years, the study analyzes the development and evolution of the engineering occupation from 1949 to 1989 and reveals characteristics of career-oriented Chinese engineers at different stages.

Second, data analysis is used. Whilst writing the dissertation, the author collected statistical data and analytical data from China's statistical yearbooks to provide facts for the investigation of the developmental characteristics of Chinese engineers, and a large amount of data allowed readers to have a more specific and direct understanding of the status of Chinese engineers such as their age, distribution and growth in number. Then, the author discusses the occupational status of Chinese engineers from an empirical perspective. Finally, the author comes up with constructive perspectives.

Third, case studies are used. This paper used this method multiple times. In the study of the history of Chinese engineers, the author tried to combine micro-studies (engineers and projects), medium (regions had industrial clusters) research and macro-research (national) together. It paid special attention to research into the status of the engineering occupation in history and its developmental course from a microscopic perspective. The second chapter, the formation and development of Chinese engineers, introduces the occupational characteristics of Chinese engineers at three stages in detail. In introducing the stages, main projects were included in each chapter to provide typical cases to the analysis of the formation and development of engineers. In addition, in Chapter 3: Vocational Education and Training, the two typical cases of engineering schools are also cited, providing a more intuitive and credible basis for discussion and giving a more detailed exposition about the characteristics of the education and training of Chinese engineers. In choosing cases, project cases and engineers that had a great influence on the development of China were selected; while cases that were controversial and local were excluded.

China witnessed several revolutions and reforms from 1949 to 1989, and Chinese engineers also went through ups and downs in the wave of history. Intertwined with the social history of China were many research directions and entry points, thus a doctoral dissertation alone cannot show the whole picture of the development of Chinese engineers. Adhering to the principle of fewer but better, the thesis took the occupational characteristics of Chinese engineers as a starting point to have a discussion about aspects such as their education and training, occupational status, groups and organizations as well as engineering's relationship with society. However, since engineering has a close relationship to society, the political changes of the country, including political activities such as the "anti-rightist struggle" (反右运动) [18] and the "Cultural Revolution"

[18] In 1957,Chinese democratic factions and some intellectuals were invited to criticize the Communist Party during its rectification movement, but their behavior was later considered antiparty and antisocialist. There was a

(文化大革命), had a direct or indirect influence on the occupational status of Chinese engineers. Therefore, although the paper focuses on the career development of the Chinese engineers' group, some political factors are also mentioned.

1.3.2 Structure

The goal of this dissertation is to give a comprehensive view of Chinese engineers and provide perspectives at the end of the dissertation. To achieve finally this goal, the author needs first of all to understand the history of Chinese engineers. After a collection of the literature, the author provides constructive perspectives and final conclusions for this dissertation. To insure this paper goes orderly and smoothly, the author has five objectives, spread across the whole paper.

The first objective is to make clear China's social changes and the development of Chinese engineers in 1949-1989. The author believes that, like other countries, the development of Chinese engineers is closely related to the social reforms and changes of national policy. This chapter includes three sections that discuss the development of the engineering profession and the effect of changes in national policy and the quality regulation of engineers at different stages so as to lay down a historical background for the book.

The second objective is to understand engineering education in China, including major approaches in the cultivation of engineers, the characteristics of China's engineering education, and its achievements and directions.

According to the occupational framework of engineers, the third objective is to research on engineers' careers and vocational status. Professional fields, opportunities of career advancement and the regulatory system are introduced in this chapter. This chapter focuses on job selection and the occupational status of engineers. Under the background of the planned economy, as a part of the state ownership, Chinese engineers encountered many restrictions in job selection as civil servants and their routine work was mainly about

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strong movement to launch a counterattack on the so-called bourgeois rightists throughout the country.

planned targets and production. This paper tries to analyze the occupational status of Chinese engineers in the premise that China targets on economic construction after the founding of the new nation from the aspect of vocational status of engineers engaged in the three industries.

The forth chapter emphasizes the introduction of Chinese engineering organizations, from the tradition of engineering organizations to the re-planning of engineering organizations after the founding of the PRC, from popular scientific and technological organizations such as the Chinese association for science and technology to elite organizations like the Chinese Academy of Sciences.

The last objective is to discuss the relationship between engineers and society in China. Moreover, the problems between four generations of engineers are discussed and the characteristics of Chinese engineers are summarized.

1.4 Review of literature

After the philosophy of science and the philosophy of technology, the philosophy of engineering, which takes engineering as its object of research, received wide attention in the 21st century. Scholars began to study engineering philosophy through aspects such as engineering education, engineering design, engineering methodology and engineering ethics and formed a research system related to engineering disciplines. According to the analysis of Wang Xukun (王续琨) on the classification of engineering disciplines and engineering history disciplines, engineering history belongs to engineering disciplines, and it is a research topic in engineering disciplines.[19] Thus, much engineering history research and engineering philosophy research contain some contents of the history of engineers. This section begins with an overview of the achievements of the academic circle in the Chinese philosophy of engineering as well as the engineering profession of China, and

[19]宋刚，王续琨，张崴: 工程哲学元研究: 创生、定位和学科结构。自然辩证法研究，第 30 卷，第 11 期。Song Gang,*et al.* eds.: Meta -study of Engineering Philosophy: Creation，Orientation and Discipline Structure. Studies in Dialectics of Nature, Vol. 30,No 11.Nov.,2014:46-53.

then it turns its focus onto introducing the literature applied in the paper.

1.4.1 Philosophy and history

1.4.1.1 Engineering philosophy and the disciplinary framework of engineering philosophy

The late 19th century is regarded as the gestation period of the philosophy of engineering. In 1966 when the *Social History of Engineering* by W.H.G Armytage was written, some commented that the field of engineering was neglected by historians. In 2003, Bucciarelli from the Massachusetts Institute of Technology published the book *Engineering Philosophy* in Europe, which attracted widespread attention. This book is based on a number of lectures given at the Technical University of Delft, where the author was a Visiting Professor hosted by the Philosophy department and the School of Industrial Engineering Design. The author explores how the concerns of philosophers are relevant to engineering thought and practice in negotiating tradeoffs, diagnosing failure, constructing adequate models and simulations, and in teaching. The book expressed the idea that engineering and philosophy seemingly belong to two separate worlds, but in reality matter and reason are inseparable and the combination of matter and reason is necessary for engineering design. In this book, the author describes how philosophers should think about the thoughts and practices of engineering, such as trade negotiation, diagnostic errors, proper construction of models and teaching activity. The book focuses on discussing some issues of engineering and engineers, that is to say, he believes there should be philosophical thinking in engineering. However, he does not state that we should construct an engineering philosophy in parallel to the philosophy of science and philosophy of technology. Starting in the 21st century, engineering philosophy received attention in China, and investment in research was obviously strengthened, leading to the tendency of "obvious speeding up" in the progress of engineering research. In 2002, Liu Zeyuan (刘则渊), Professor in the Arts and Humanities Department of Dalian University of Technology, published a set of annals of research into *Engineering, Technology and Philosophy* with contents about engineering philosophy, engineering and technology from a new perspective as well as engineering ethics; however, its main focus was research into technology and philosophy. It is easy to see that the editor consciously brought the unfamiliar field of engineering philosophy into people's view, instead of simply emphasizing its relationship with technology and philosophy. In 2002, Chen Changshu (陈昌曙) published the article *Emphasis on Engineering, Engineering Technology and Engineers,* which clarifies that engineering should not be confused with technology. Ten characteristics of engineering are listed with a conclusion: "engineering is closely connected with technology, but they are different as engineering has its relative independence and particularity. Thus, engineering should be discussed specifically." With over 20 years experience of studying engineering philosophy, Li Bocong (李伯聪), Professor of the Humanities Department at the Chinese Academy of Sciences defined its core concept "engineering" in *An Introduction to Engineering Philosophy: I Create, Therefore I Am* in the same year as the generic term for a human being's whole practical activities and processes in transforming nature. The article also demonstrates the dialectical interrelation and inter-conversional relationships of science, technology and engineering and puts forward their plural relationship, which expands the traditional dual relationship of science and technology and lays the foundation for the establishment of philosophy of engineering. Later, Li published a set of articles called A *Study on Engineering Community* in *Journal of Dialectics of Nature* including several issues about workers in the engineering community and engineers, aiming to study the main body of engineering in detail. Compared to science and technology, engineering - which contains workers, engineers, investors and governments - is more complicated. In the article '*On Several Problems about Engineers*', Li mainly discusses the derivation of the word "engineer", engineers' job characteristics, engineering knowledge, engineers' career predicaments and engineers' job responsibilities. Finally, he mentions engineers' prestige and social status. According to him, the profession of engineering is ignored and enjoys low social prestige, which is evident in China. He advocates paying attention to engineers and engineering masters, developing engineer experts' and masters' extraordinary innovation ability and leadership skills as these can ensure that engineering groups are not being overlooked.

In July 2007, *Engineering Philosophy* was published, which was edited by Yin Ruiyu

(殷瑞钰) who is a member of the Chinese Academy of engineering, the course leader of the project "*studies on engineering philosophy*" from the Chinese Academy of Engineering. More than 20 authors of the book tried to systemize, analyze and study engineering from a broader and deeper philosophical perspective and then preliminarily sketch the basic ideas, opinions and theoretical framework of Chinese engineering philosophy studies. As the first engineering philosophy work under engineers' and philosophers' cooperative research and repeated dialogues, it not only has academic value but is also an important sign of "alignment" in the fields of engineering and philosophy. It should be noted that this book is a philosophical case study on important engineering events in the period since the foundation of the PRC, which diversifies research methods, catering more to engineering philosophy's characteristics and making it easier to solve practical problems. After that, with works like *Evolutionary Theory of Engineering*, *Introduction to Engineering Sociology* and *Engineering Innovation* successively came into the market, with scholars in the field continuously enriching the whole system of engineering philosophy, putting forward problems to be studied from different perspectives of the philosophy of engineering and offering their own views.

However, an engineering philosophy system has not yet been set up. Since 2004, the Engineering and Social Research Center of Graduate School, Chinese Academy of Social Sciences, has continuously published the *Journal of Engineering Studies*, which is mainly focused on the new concept "Engineering studies" and advocates studying the "engineering phenomenon" from various interdisciplinary perspectives such as philosophy, history and sociology. This may help to establish "engineering research" as a transdisciplinary and multidisciplinary research field to enrich the content of research in the philosophy of engineering. The academician Yin summarized six aspects of engineering philosophy: "1) the definition, categories, levels and scales of engineering philosophy; 2) the position of engineering activities in the social activities as well as the law of engineering development; 3) theoretical analyses and philosophical studies on the concept, decision-making and implement of engineering; 4) studies on engineering ethics and engineering aesthetics issues; 5) case studies on major engineering projects and researches on the history of engineering; 6) engineering education and public understanding of engineering."[20] Therefore, aspects like research into the history of engineering, case studies on major engineering projects and engineering education were brought into the field of engineering philosophy studies.

1.4.1.2 Research on the history of engineering

The term 'History of technology' was considered to have originated from the setting up of 'Technologic' by J. Beckmann at the German Georg August University of Gottingen in 1722, which contained two contents: Engineering and the history of engineering technology. In the whole 19th century, nearly every work on the history of technology, including H Poppe's *Geschichte der Technologie (1807)*, K. Karmarsch's *History of Technology* (1872), Hoppe's *Beiträge zur Geschichte der Erfindungen* (1880), C. M. Rühlmaun *Vorträge über Geschichte der Technischen Mechanik* was written by Germans. After entering the 20th century, studies on the history of technology rapidly developed worldwide. In 1909, in Germany *Beiträge zur Geschichte der Technik und Industrie* were established which were renamed as *Technikgeshichte* in 1965 when its publication was resumed by the VDI (Verein Deutscher Ingenieure). The *History of Technology* with chief editor C. Singer, which was sponsored by the English Imperial Chemical Industries Limited was published since the 1950s; it is the largest work for the comprehensive history of technology up until now. In 1962, four volumes of the *Comprehensive History of Technology* were compiled and published by the Frenchman M. Daumas.

In 1958, the American Academy for the History of Technology was set up. It held academic meetings annually in North America and Europe. In 1968, the International Committee for the History of Technology (ICOHTEC) was founded, and played a positive role in communicating the history of technology between Eastern and Western countries. In 1967, two volumes of *Technology in Western Civilization* by M. Kranzberg and C.W. Pursell were published and taken as a textbook by many universities. At the beginning

[20]殷瑞钰：哲学视野中的工程。西安交通大学学报(社会科学版)，2008(1)：1-5。Yin Ruiyu: Engineering in Philosophical Vision. Xi'an Jiaotong University (Social Sciences) (2008) (1): 1-5.

of the 21st century, the research direction of the history of technology changed somewhat and engineering issues related to technology were put forward. *A History of Engineering and Technology: Artful Methods* written by Ervan G. Garrison, Professor of Geological Sciences and Anthropology at the University of Georgia in America, was a masterpiece about the history of engineering. On the whole, this book is different from such famous works about the history of technology or the history of technology and science as Singer's *History of Technology* or Joseph Needham's *Science and Civilization in China* because it mainly focuses on engineering instead of technology and science. Furthermore, it is different from specialized history subjects in the engineering discipline like iron smelting history, bridge history and railroad history, as it prefers a comprehensive history. It is not only a chronicle of engineering but also a book about the conceptual and social history of engineering. In Garrison's opinion, "Engineering is one of the oldest applied arts with a unique combination of concrete needs and special designs in the process of producing some creative work or products". Thus, Garrison holds that "it is proper to treat engineering as an art as well as a method and a name for a book".[21] As for its research characteristics, engineering rather than technology is taken as the research object. In its content, engineering blends with cultural anthropology. In its method, demonstrations and theories on history of archaeology are combined. Thoughts on evolution are also contained as ways of developing engineering. Based on this book, the variety of engineering that exists in the history of engineering can clearly be seen. In addition, continuity and novelty exist between different categories of engineering and engineering in the same category.

In the article *Some Issues About the Modern History of Engineering in China*, Li Bocong (李伯聪) combines the history of science, technology and engineering to present a detailed dissection of the research objects of the history of engineering. He says, "in engineering activities, engineering decisions are key links and content while technical decisions are important components and factors of engineering decisions. However, the essences of engineering decisions are normally not important components and factors of simple technical decisions. Also, the essences of engineering decisions are normally not

[21] Ervan G. Garrison. A History of Engineering and Technology: Artful Methods. CRC Press,1999, Preface.

simple technical decisions as many major engineering decisions have strong political nature."[22]

In the essay *Evolution and Challenges of Civil Engineering*, Mathew Abraham reviews in detail the evolution and future trends of civil engineering from the perspective of the expansion of spatial development, which includes the evolution of not only highway engineering, railway engineering, bridge engineering and waterway engineering but also space engineering such as the evolution of International Space Station and Mars exploration. Moreover, this essay contains a review of the evolution of civil engineering by text and pictures to explain how the progress of key technologies promotes construction technology and methods. Furthermore, the essay discusses the challenges to be faced by future civil engineers in constructing more complex works in an abnormal and disadvantageous environment.

In the book *History of Engineering and Society*, the English scholar W. H. G. Armytage discusses the development of technology and engineering, especially the development of engineering and technology in the UK, by illustrating their brief history, revealing how these developments influence and become influenced by social life at some stage and provides enlightenment on the origins of the innovation system. It can be seen that the history of science and technology are two different disciplines that originate independently and develop separately. The history of engineering belongs to the history of technology and has drawn widespread attention since the beginning of the 21st century.

China adopted the interfluent model by combining the history of science with the history of technology when it stated to institute these two disciplines in the 1950s. It was mainly influenced by the USSR's Academy of Science - its institute for the history of science and technology - the first to combine the history of science and technology and represent a new ideological orientation. In 1956, China set a *12-year long-range ground plan* for studies in the history of natural science and technology, especially when it drew up a

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[22] 李伯聪：中国近代工程史研究的若干问题，第30卷，第六期。2013年12月：63。Li, Bocong, Some Issues About the Modern History of Engineering in China. Studies in Philosophy of Science and Technology.Vol.30,No.6,Dec.,2013:63.

long-term plan for scientific and technological development. In 1957, the institution of the history of natural science at CAS was set up. It drafted the developmental outline for studies on the history of natural science from 1958 to 1967, in which the words "history of technology" were secretly deleted. Since then, the history of technology in China lost its independence and was attached to the history of science. This fading out of the history of technology weakened the disciplinary position of the history of engineering.

At the beginning of the 21st century, the history of engineering was independent from the history of technology when engineering philosophy became a buzz phrase in the academic world. In China, the history of engineering occupied an indispensable position in studies on engineering philosophy. Yin Ruiyu showed several times that studies on the history of engineering were among the "fundamental" works for engineering philosophy and the history of engineering should become "a breakthrough point for studies on engineering philosophy".[23] Li Bocong also once adapted Kant's famous sentence structure: "Engineering philosophy without the history of engineering is barren, meanwhile, the history of engineering without engineering philosophy is blind";[24] he thought that the history of engineering had a significant position and would affect engineering philosophy.

Concerning the classification of disciplines, the history of engineering should be an interdisciplinary subject between engineering and history, which means that the history of engineering is the interdisciplinary branch of engineering and should belong to engineering studies. However, comparing it with the relationship between science studies, the philosophy of science and the history of science, it is easily acknowledged by the academic world that the primary history of engineering, engineering studies and the continuously developing engineering philosophy should be taken as congenetic disciplines.

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[23] 殷瑞钰：哲学视野中的工程。西安交通大学学报 (社会科学版)。2008(1)。Yin, Ruiyu: Engineering in Philosophical Vision. Xi'an Jiaotong University (Social Sciences) (2008) (1): 1-5.

[24] 李伯聪：中国近现代工程史研究的若干问题。科学技术这学研究。第三十卷第六期，2013 年 12 月。Li, Bocong: Some Issues About the Modern History of Engineering in China. Studies in Philosophy of Science and Technology,Vol.30 No.6 Dec.2013:61-67.

However, professional works on the Chinese history of engineering are not available. Moreover, it should be noted that the first seminar on the history of engineering held by the Chinese Academy of Sciences on November 28th 2010 started the studies on the domestic history of engineering. Up until now, studies on the Chinese history of engineering have paid more attention to the evolution of the specialized history of engineering or technology (industry). For example, Wang Dewei (王德伟) conducts a philosophical analysis of the evolution of specialized industry, such as the iron and steel industry, in his doctoral dissertation *Philosophical Thinking on the Evolution of Iron and Steel Industry*. Based on domestic and foreign steel production growth, the dissertation conducts case studies of the Chinese iron and steel industry. Through analyses of the technology imports of Wuhan Steel Company and case studies of Anshan Steel, Baosteel and Shougang, it reveals the transition mechanism and modes of evolution of the iron and steel industry by metallurgical process engineering.

Wang Hongbo gives detailed studies and analyses of social engineering in *Engineering Philosophy and Social Engineering*. This book clarifies social engineering objects and especially discusses the methodology of social engineering including the social analysis method, design technique and model analysis approach for social modes and social choice theory. Thus, it provides basic ideas and approaches of coordination analysis and a sociological research process for studies on the history of engineering. In 2013, Li Bocong published the article *Some Issues in the Modern History of Engineering in China*, which generalizes studies on the history of Chinese engineering.[25] The report shows that the modern history of engineering in China is one that transformed in form and system from ancient times to those of in modern times. In addition, the article discusses the developmental stages and bases of the modern history of Chinese engineering. Engineers and technicians, including those from China, attach great importance to this new research field of "engineering philosophy", with such content as studies on the history of engineering and studies on

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[25] 李伯聪：中国近现代工程史研究的若干问题。科学技术这学研究。第三十卷第六期，2013年12月。第61-67页。Li, Bocong: Some Issues About the Modern History of Engineering in China. Studies in Philosophy of Science and Technology,Vol.30 No.6 Dec.2013:61-67.

typical engineering cases.

1.4.1.3 Research on the history of engineers

Max Müller said: “Can you teach mathematics without teaching the laws of thought, without telling your pupils something about such men as Thales, Pythagoras, and Euclid, who were ancient Greeks, but who were men of science for all that? You mean to teach physiology and biology,the laws of life and nature. Are you likely to leave out the very crown of nature man--to leave nature like Hamlet without the Ghost, a nature without its spirit?...To attempt to study nature without studying man is as impossible as to study light without studying the eye.”[26] In the second half of the 20th century, the theme of engineering was under-investigated, as argued in the inauguration speech made by John B. Rae, Chairman of American Technology and History in 1974. He argued that engineers were ignored in history and suggested that this defect should be corrected.[27]

Research of engineers and their profession received more attention at that time, articles about studying on the engineering profession were published such as: *The Engineer and His Profession* (John Dustion Kemper,1967); *What engineers Know and How They Know It* (Walter G. Vincenti, 1990), a historical reflection on engineering practice in US aeronautics. Five case studies from the history of aeronautical engineering are used to argue that engineering often creates its own scientific discoveries, to reveal patterns in the nature of all engineering which form an “epistemology” of engineering that may point the way to an “engineering method” as something distinct from scientific method. E. T. Layton, Jr.’s *The Revolt of the Engineers. Social Responsibility and the American Engineering Profession* (Layton Jr E T. , 1986) emphasizes professionalism, social responsibility, and ethics. It explains how some engineers have attempted to express concern about the social effects of technology and to forge codes of ethics that could articulate the profession’s fundamental obligation to the public. *The Professional Engineer in Society: a Textbook for engineering students* (Stephen Collins, John Ghey, Graham Mills, 1989) asked, “is engineering a real profession?”. *The New*

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26 Müller, F M. :The life and letters of the right Honorable Friedrich Max Müller. Longmans, Green, 1902: 94.

27 T. S. Reynolds ed.: The Engineer in America .Chicago: The university of Chicago Press, 1991.

Engineer (S. Beder, 1989), discussed the issue of professional moral standards as engineers.

In addition, some scholars discuss the history of engineers in the individual country or region, such as：*The engineers: A history of the engineering profession in Britain, 1750-1914* (Robert A. Buchanan, 1989) discussed the development, prosperity and responsibility of British engineers since the First Industrial Revolution. *The Professional Engineer in Society* (S.Collins, ed., 1989). *The Engineer in America* (Reynolds, 1991). *Engineers in a Developing Country: The Profession and Education of Engineering Professionals in South Africa* (R. Du Tolt and J. Roodt, 2009) discuss educational problems and the development dilemma of South Africa's engineers. *Geschichte des Ingenieurs Ein Beruf in sechs Jahrttausenden (History of the Engineer: A profession in six millennia)* (Walt Kaiser and Wolfgang König, ed.) is mainly about the history of engineers in the West from early civilization to the modern world. This book supported by the VDI holds the new concept that engineering is an occupation with a long history. Along with technological advances, the formation of the prosperity of engineers in Germany, France, Britain and America was introduced through education, training, policy, organization and so on. This is a systematic book for recent engineering professional group research. However, as this book concentrated on the engineering profession in the West, it motivated the author to investigate the formation of engineering and engineers' technological development under the Chinese social system, which will provide an insight into a new aspect of engineering studies.

In the existing research, academia has investigated the status and role of engineers, and the issues of engineers' knowledge, ability and quality for a long time with many valuable results. Since the 1980s, in the process of industrialization, modernization and marketization of the whole country, the problem of occupational prestige has become one of the key concerns of China's sociological circles. Some scholars have pointed out that although engineers played a significant role as the main body of engineering, the philosophy, history and sociological research into the engineering profession were still fragile. For China, there is still blank research on the group of Chinese engineering professionals. Scholars attach more importance to the history of engineering and the development of individual engineers as trying to generalize the development of engineering. They also try to introduce a section of outstanding engineers engaged in engineering or to review the development of specialized technology made by Chinese engineers, such as the engineer, Zhan Tianyou (2004), [28] *Hou's Process for Soda Manufacture in China* (2009).[29] However, scholars emphasize engineers' personal qualities more , and less the analysis of the objective conditions of society - enterprise and education that influence the engineer. China has made remarkable achievements in some areas of science and technology but, in general, Chinese scientists and engineers have made fewer achievements for the development of world science and technology. However, Chinese engineers play a crucial role in contributing to their country's economic development and construction. This essay focuses on promoting the role that Chinese engineers play in the development of China's national economy. It has no intention of discussing the particular functions and qualities of all engineers, but rather searches for their general characteristics.

1.4.1.4 Research on the Chinese science and technology occupational group

After the founding of new China, engineers were listed among the ranks of the intelligencia - investigations into them as a professional group were not carried out in the last century. Chen Chuyuan made a detailed analysis of science and technology policy after the foundation of the PRC, and the situation of the human resources of science and technology in his book *Scientific and Engineering Manpower in Communist China, 1949-1963*. This book concludes a large number of data and analyzes educational training and the career status as well as the political and social status of scientific and engineering manpower in China. However, most works prefer to study the occupational status of engineers and technicians in terms of the political system, the economy, science and technological policy. These works are: *Research and Revolution Science Policy and Societal Change*

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[28] 张治中：工程家詹天佑。工程研究 - 跨学科视野中的工程。2004。 Zhang,Zhizhong: Engineering Master: Zhan Tianyou. Journal of Engineering Studies, 2004：193-204.

[29]叶青：联合制碱在中国，工程研究 - 跨学科视野中的工程，2009年第四期。Ye,Qing: Hou's Process for Soda Manufacture in China, Journal of Engineering Studies.No.4,2009:368-379.

in China (Richard P. Suttmeier, 1974), *Technology and Science in the People's Republic of China* (Jon Sigurdson, 1980), *Rise of the Red Engineers: The Cultural Revolution and the Origins of China's New Class* (Joel Andreas, 2009), *Chronicle of Science and Technology of China 1949-1989* (Guo Jianrong, 1990), *Chinese Characteristic Industrialization* (Ye Liansong ed., 2005), *Study of Intellectual Economic Policy - the Innovator's Solution* (Zhou Fangliang, 1989), *The Choice and Exploration of Chinese Intellectual* (Pei Yiran, 2004), *Chinese Intellectual and Chinese Social Revolution* (Jia Chunzeng, 1996). *Studies on the Education and Training about Chinese engineering technician include General Education Theory* (Yang Dongping, 1989), *Study of Beijing Higher Engineering Education Reform 1949-1961* (Hang Jingfang, 2008), *China Learns from the Soviet Union, 1949–Present, Lexington Books, Social Demands and Curriculum: Based on Investigation in Engineering Colleges* (Wu Junqing, 2010) and *The Quality and Ability of Modern Engineers* ('Engineers Forum' editorial department, 1988). Studies on Chinese engineering technician occupational situations include: *The Personnel Management of Contemporary China* ('Contemporary China' editorial department, 1994) and *The Study on the Conditions of Chinese Modern Engineering Technical Expert Group* (Fang Heihu and Xu Fei, 2003). Studies on scientific thoughts of Chinese engineering technician include: *The Study of Contemporary Chinese Technology Outlook* (Jiang Zhenhuan, 2006) and *Chinese Contemporary Scientific Trend* (Yan Bofei, 1993). Studies on major engineering projects include: *The Project of Atomic and Hydrogen Bombs and Satellites and Science* (Liu Jifeng, Liu Yanqiong, Xie Haiyan, 2005) and *China's Significant Engineering Achievements in the 20th Century* (Chang Ping ed., 2002). Studies about engineers include: *The Memorial Publication of the Thirtieth Anniversary of Chinese Engineers*, Chinese Science and Technology Group (He,Zhiping, 1990), *History of China's Civil Engineering Society* (Chinese civil engineering society ed., 2008), *The Complication Data of the Chinese Academy of Sciences 1949-1954 (Office of the Chinese Academy of Sciences ed.,1955), Chinese Intellectuals and Science A History of Chinese Academy of Sciences* (Shuping Yao, 1989), Magazines of Chinese Society of Electrical Engineering (2009), *Contemporary China Series --- Contemporary China Series of Historical Development Summary by Technology Association of the Chinese Academy of Sciences --- the Chinese Academy of Sciences*, the first and second volume (Qian Zhanlin, GuYu, 1984), in particular, the first section of the sixth chapter.

On the whole, the existing studies of Chinese engineers still have some defects. There are still some gaps around the studies of Chinese engineers as an independent occupational group, such as the education and training of Chinese engineers. Chinese engineers' working conditions under different political and economic policies, and the relationship between Chinese engineers and wider society remain to be further studied. Based on former studies, this paper will study the development of Chinese engineers and their professional characteristics after 1949 according to the following categories of documents.

1.4.2 Main literature references

Besides its predecessors' research achievements, the primary literature references of the essay include documents, newspapers and magazines, engineers' biographies and memoirs and some statistical data and so on. These materials are introduced as follows.

1.4.2.1 Archive materials

Archive materials are the primary sources of this paper including some unsorted original archives scattered in various archives at present and literature compilations or collections based on archive materials by different departments. Archive materials can help grasp historical events, such as Zhou Enlai in the book *Report on the Question of Intellectuals.*

Previous researchers have undertaken all kinds of archive compilations or collections, which provide convenient conditions for further study. These archive materials include *The important literature compilations Since the founding of Chinese Republic of China*, *Chronicle of science and technology of China 1949-1989,* People's Publishing House, *The Annals of Statistics on Science and Technology of China, National Bureau of Statistics*, *China's Educational Performance Statistics1949-1983, Contemporary China series, China Social Sciences Press and Planning Department of the Ministry of Education of the People's Republic of China, Material Compilations of the Chinese Academy of Sciences1949-1954, Literature Compilations of the Relationship Between China and Soviet Union 1949-1951, Economic Memorabilia of Chinese People's Republic of China 1949-1984, China Education Yearbook* 1949-1981, *Manual Data Summary of China's the Third Population Census,* *China's Agricultural Mechanization Memorabilia 1949-2009, Complications of Education Law Literature 1963*, *Data Office, State Statistical Work Bulletin, China's Workers, 1955: Their Number, Composition, and Distribution*.

1.4.2.2 Newspapers and other publications

Compared to archive materials, newspaper and magazines are more timely. *People's Daily and Guangming Daily* have provided a large number of reports and related data of various aspects about engineers from 1948 up until now. *Red Flag* over 29 years from its first issue to the year of 1987, as the propaganda organ of the party's main thoughts and policies in economic science and technology, contains a lot of articles about the party's view of engineers and scientific and technical workers. *Chinese Science Bulletin* started publication in 1950 and was dedicated to the latest research in natural science and the newest research trends of applied research dynamics, subject development patterns and so on. The magazine studies the dynamic of domestic science and technology, providing a reference for the writing of this paper. *Engineers Forum (Chinese：工程师论坛，Gongchengshi Luntan, Now: Chinese Software Engineers)* as a national magazine aimed at engineers communication was founded in 1985. The magazine focused on planning and held an engineers' forum, as well as an introduction of advanced technology and outstanding engineers. The magazine helped the author gain a better understanding of Chinese engineers' development in the 1980s. *China Quarterly* started publication in 1960 and was sponsored by the School of Oriental and African Studies. This magazine includes modern China and Taiwan, and also includes anthropology, business, literature, art, economics, geography, history, foreign education, law, politics and so on. This magazine is mainly committed to promoting the academic research of China from the point of view of Western countries, and is an important publication of academic research into the modern history of China and the history of People's Republic of China made by Western scholars. The magazine provides the basis for this paper's study of the history of Chinese engineers from various perspectives and makes up for the shortcomings of some domestic literature.

In the era of paper media, universities and companies started the publication of school newspapers and factory publications. For example, *New Tsinghua* recorded the education reform of Tsinghua University from the 1950s, reporting that Tsinghua University was the 'cradle of the red engineers' and so on. In addition, a selection of experts' reports of colleges and universities are available in the university library and national library.

1.4.2.3 Memoirs and biographies

Memoirs and biographies present us with a vivid history. Taking memoirs as an example, a number of major decisions and events as well as significant historical decisions and science and technology policies after the foundation of PRC were reviewed. Biographies are also the key collecting target of this study. In addition to the biographies and chronicles of central leaders, some biographical works of scientists and engineers who influenced the process of China's science and technology have been edited and published successively. For example, *China Science and Technology Experts Profile* and *Complication of Engineering Technology* take modern outstanding scientific and technological Chinese experts as the main path to describe the history of the development of Chinese modern science and technology. *China Science and Technology Experts Profile* is divided into four parts including science, engineering, agriculture and medical science. The lives and outstanding achievements of engineering experts in the *Compilation of Engineering Technology* provide detailed and reliable historical data for writing this paper. In addition, there are some personal biographies, such as *The hydraulic engineer --Wang Huzhen (Jiaxing Municipal CPPCC Committee of Cultural and Historical Data, 1997)*, and *The epic elegy of Huang Wangli and Sanmenxia dam projec*t (Xu Shuitao, 2007) and so on. However, it also records the engineers' difficulties and achievements in the process of self-fulfillment from another aspect, and how engineers make engineering decisions in the implementation of important engineering projects. These facts have great significance for studying Chinese engineers.

1.4.2.4 Other historical data

In addition, some school materials and historically recorded data about major engineering projects are also valuable resources for studying the education, training and occupation of engineers. Since the 1990s, university historiographies have become familiar. For example, Tsinghua University and North China Electric Power University, the research target of this paper, started publication of school histories, including the *Annals of Tsinghua University* and *School History of North China Electric Power University 1958-2008* and so on. Records of major engineering projects include Chinese Modern Science and Technology is the Series of Research: *The project of Two Bombs, One Satellite: A Model of The Big Science*, *Documents of Steel Construction,* compiled by Chinese People's Political Consultative Conference Literature, History and Learning Committee, and *History of China's Major Technical Equipment,* complied by China Machinery Ltd.

1.4.2.5 A note on Statistics

The paucity of statistical data and the deterioration of the whole statistical system beginning in 1958 made it impossible to arrive at any precise estimates concerning scientific and technical manpower. To date, no comprehensive statistics are available regarding the age brackets and employment of Chinese engineers. To fill in the gaps in the existing material and to provide the basis for a cross-checking, a rather particular type of survey was undertaken. In this investigation, *Chinese Engineers' Names* compiled by Zhang Guangdou, who was a hydraulic engineer at the Chinese Academy of Engineering, is used as a sample, which contains 15,000 entries with each introducing an engineer. This book not only includes some personnel with famous or significant technological achievements from the foundation of the PRC to 1988, but also includes a few personnel engaged in basic theoerical engineering technology research or the management of engineering technology. The contents include the names, genders, nationalities, dates of birth, the higher education and majors, main duties and social responsibilities, main work experiences, honorary titles, main works, postal addresses, phone numbers and nationalities of engineers. The book classifies professions that engineers engaged in into 27 kinds of 115 small classes, which includes the most detailed biographical data, introducing famous particular engineers since the foundation of the PRC. Taking the engineers' group as a sample, the data analyzes some necessary information, such as the engineer's level of education, their foreign study situation and graduation age since the foundation of the PRC. On the other hand, its data also comes from the natural science and technology personnel statistics released by the state-owned State Statistics Bureau, including the main data from the years 1952, 1960, 1978, 1980-1988, census data of professional technicians and relevant data released by *People's Daily*. Most of the data for this survey was compiled from scattered sources, resulting in inevitable contradictions. Although a particular effort was made to minimize inconsistencies, the statistics presented are subject to a wide margin of error. However, they provide some basis for estimates in these areas and lay the foundation for further study of the subject.

1.5 Limitations and further study

This dissertation has some limitations - the paper lacks empirical studies on the social position of Chinese engineers and an investigation of social mobility of different kinds of engineers. The targeted engineering professionals do not include Chinese engineers in Hong Kong, Macau and Taiwan, while engineers abroad were also not considered. The process of the growth and development of Chinese engineers in terms of technological progress would need profound and precise investigation. As part of a Chinese history of engineering research, more issues would require further research such as engineering training, the qualification system of engineers, and engineers' status.

Chapter 2: The formation and development of Chinese engineers

As in other countries, the development of Chinese engineers is closely related to social reforms and changes in national policy. So, in this chapter three sections discuss the development of the engineering profession and the effect of changes in national policy and historical details related to engineering events at different stages. Regarding the division of engineering into developmental stages, the author holds similar opinions to Li Bocong, in his article *Issues of Modern Chinese History Research in Engineering*. The development of Chinese engineers from 1949-1989 is divided into three stages, it also a way of separating the stages of "Political History". This is because after 1949 the CCP fully integrated the national science and technology policy into the national political management system. Each phase of the economic, scientific and technological policy has dominated the development of engineering, and this has led to significant changes to the development of Chinese engineers, the educational environment as well as the treatment of work. Consequently, to understand the formation and development of Chinese engineers, it is necessary to review the major events that transpired during the three periods of the Chinese scientific and engineering regime. Moreover, the most critical point in each stage has become how to put the characteristics of political history aside to discuss engineers' development, and how to analyze the particular historical characteristics of engineers.

2.1 Socialist transformation period 1949-1965

2.1.1 Status of Chinese engineers before 1949

As opposed to most industrialized countries, the origin of modern engineers has no close relationship with technological progress in China. There was no internal power for China's emerging engineers. The country's weakness in the 19th and early 20th centuries in the face of a technologically superior West called for the development of science and technology as a project of national salvation. Chinese engineers emerged during an era when national and social crises coexisted. They were endowed with dual roles in modern society: On the one hand, they were the social carriers of the national culture; on the other, they were also a social elite necessary for the nation's political entities. Actually, the advanced technology utilized by Western powers had thoroughly changed the ways of thinking of the entire Chinese society, making the government and the nation begin to cultivate and train in an organized way a batch of people targeted to be engineers. From the perspective of technological history, it is impossible for participants to choose their social conditions. Therefore, there was no way for a region or a country to thoroughly change its social condition and have a technological transplant. In view of this, it urgently called for such participants to not only master technology but also be capable of, through their activities, having technology rooted in the nation under its current social conditions. Chinese engineers were the people who played such a role and experienced the following three phases in their actions as an independent group.

2.1.1.1 Traditional intellectuals in the Qing Dynasty

After the Opium Wars (1839-1842), *The Chinese Serial* (遐迩贯珍) was published in Hong Kong, which was an article on the "mechanism of the steam engine" illustrating the working principle of the steam engine with simple drawings. It can be imagined what a tremendous impact it had on traditional Chinese intellectuals. Afterwards, traditional intellectuals represented by Li Shanlan (李善兰), Xu Shou (徐寿), Hua Hengfang (华衡芳) and Zhang Fuxi (张福喜) were engaged in science and engineering, translating numerous books related to Western science and technology, setting up academies to teach science and technology and participating directly in the design of early industrial equipment and so on. However, their research objects, research methods, research techniques or achievements were still covered by the field of traditional science and technology. They still belonged to the old Chinese intellectuals who introduced Western science and technology to China; although they had some of the activities of an engineer, they were not engineers in the real sense.

2.1.1.2 Early Chinese engineers in the late Qing Dynasty

Sending students abroad during the self-strengthening movement (1861-1895) was a landmark in the history of the Chinese engineering profession, representing the first step towards institutional engineering training in China. After the engineering students such as mining and metallurgical engineer Kuang Rongguang (邝荣光), mining engineer Zeng Pu (曾溥) and railroad engineer Zhan Tianyou (詹天佑) returned, they engaged in engineering work such as shipbuilding, railway and telegraphy construction.[30] The engineers played a significant role in the Westernization movement and early stage of Chinese industrialization.

2.1.1.3. The proliferation of engineers in the Republic of China(1911-1949)

During the 1920s-1930s, Chinese engineering began to flourish. Its proliferation benefited from three facts:

A. The new government's emphasis on Industrial Policy. In 1919, Sun Zhongshan (孙中山), the leader of the Nationalist Party, enacted "The International Development of China", where he suggested carrying out industrial construction in the whole country, including railway construction, transportation, oil and coal prospecting, light and heavy industry and so on. [31]The Nanjing Government had set up the Ministry of Industry, working out various policies and laws to protect industry and to encourage people to set up companies and factories. In August of 1928, at the Fifth Plenary Session of the Second Nationalist Party, Kong Xiangxi (孔祥熙), the Minister of Commerce and Industry, had actually proposed a solution to develop state-operated industry and included those industries necessary for the national interest and people's livelihoods, such as machinery,

[30] 李喜所：《中国近代早期留美学生小传》。南开史学，1984 年第一期。Li Xisuo: Biography of Returned Chinese Students in Early Modern, Nankai Shi Xue,No.1 1984.

[31] Sun, Zhongshan: The International Development of China. G.P. Putnam's Sons, New York and London: The Knickerbocker Press.1922.

steel and iron, hydroelectricity, chemical industry, textile manufacturing, salt manufacturing and papermaking etc. into the scope whereby only the government had the right for investments and startups. For a while, engineers became the most urgently needed of talents.

B. Achievements were made in engineering education. The 1912 National Government promulgated a new higher education policy called "Renziguichou", which included: Foundation degrees, undergraduate degrees, graduate school; the study of modern Western science courses; an implementation degree system, and the setting up of a council to engage professors. By 1947, there were 55 universities (31 public, private 24), with 33 Engineering Institutes among them. According to the policy, there were 11 engineering disciplines: Civil engineering, mechanical engineering, marine engineering, naval architecture, weaponry design, electrical engineering, architecture, applied chemistry, gunpowder science, science of mining, metallurgy.[32]

Since the 1920s, with the increase in the number of qualified teachers, as a result of the numerous engineering students who had studied abroad with advanced degrees returning home, and promoted by the Chinese Institute of Engineers, Chinese higher engineering education then entered a period of fast development. The Nationalist Government, in turn, had implemented a policy of "focusing on the industry", which further promoted the development of higher engineering education. Tsinghua University, Peking University, Central University, Nankai University, Wuhan University, Peiyang University, Concordia University and Nanking University, etc. had all also established engineering institutions. By 1936, there were 36 technical schools in China with the number of students in the schools numbering 6,987.[33] While "for the various engineers in China, the total number was estimated to be over 5,000."[34] Meanwhile, with the help of the KMT

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[32] 纪宝成：中国大学学科专业设置研究，北京：中国人民大学出版社，2006。Ji, Baocheng: Research on Chinese University Curriculum setting, Beijing: Renmin University of China Press,2006:11-14.

[33] 陈立夫：中国工程教育问题。工程，第13卷4号。1940，8。Chen, Lifu: The questions about Chinese engineering education. Engineering, Vol.13 No. 4 ,1940,No.8.

[34] 庄前鼎：国内工程人才统计。工程。第11卷第1期。1936，2。Zhuang, Qianding: Domestic engineering talent Statistics. Engineering. Vol. 11,No.1,1936,No.2.

government and social finance support, in May of 1927, at the 90th conference held by the Political Bureau of the Central Committee of the Nationalist Party, a preparatory office was established for the Academia Sinica. After preparation, on July 4, the Nanjing government published "The regulation on the organization of the universities of the Republic of China", stipulating university as the highest education authority in the country to govern the various academic and educational administrative affairs of the nation, with the Academia Sinica affiliated to the university.

By January 1935, 142 academic research organizations and institutions had been established. Some of the institutions were well known in the country including the Geological Survey of the Ministry of Geology, the Health Lab of the State Economic Commission, the Central Agriculture Lab and the Biology Institute under the Science Society of China, the Huanghai Institute of the Chemical Industry, the Chinese Western Academy of Sciences and Shanghai Leiside Institute of Medicine etc. After the CCP had rebuilt the government, these institutions were retained.

C. The association of engineers made the engineers' group more mature. After Zhan Tianyou established the "Guangdong Association of Chinese Engineers" by gathering all of the comrades in 1912, many associations of engineers were set up, such as the Chinese Engineering Society. Because of their similar goals, these associations were merged in 1931 to become the Chinese Institute of Engineers (CIE), which became the only comprehensive engineering and academic society in China, making it the natural leader in engineering circles at that time. According to the record of association, in 1931 there were 2,169 members in the newly established Chinese Institute of Engineers. As shown in the following Table 2.1, this figure had risen at a stable rate by 100-200 members per year. The establishment of the various associations and the development of the branches in different regions made the engineer groups more closely united for the better development of the engineering cause to providing professional consultancy services to the government in terms of engineering and education, etc.[35]

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[35] Edit by Chinese engineering association: Chinese engineering association at anniversary ---three decades of Chinese engineering, Chongqing: Central Publishing House.1948.

Table 2.1 Statistics for the members of Chinese Institute of Engineers (1931- 1949)

Year	Membership Individual	Membership Group	Year	Membership Individual	Membership Group
1931	2,169	—	**1941**	4,263	43
1932	2,435	—	**1942**	5,194	49
1933	2,600	—	**1943**	6,731	71
1934	2,734	—	**1944**	9,424	126
1935	2,982	—	**1945**	9,482	126
1936	3,069	—	**1946**	11,079	129
1937	2,994	17	**1947**	12,730	129
1939	3,290	26	**1948**	15,028	129
1940	3,290	26	**1949**	16,717	129

Source: 房正：中国工程师学会研究（1912-1950），博士论文，复旦大学，2011。Fang,zheng: Researches at the Chinese Institute of Engineers 1912-1950, Doctoral thesis Fudan University.2011: 64.

The Chinese Institute of Engineers had been committed to promoting the industrialization process in China. Since its foundation, the institute had carried forward various academic exchanges with platforms such as an engineering magazine and its annual meeting to promote the development of modern academic engineering research. The compilation and validation of engineering terminologies was one of its explicit goals in the early period of the institute. Originating in the West, some engineering terminologies inevitably led to a variety of ambiguity or errors in the translation process. Recognizing the importance of unifying engineering terminologies, Zhan Tianyou led the institute to collect and translate the terminologies at very early stages and edited them into the *New Chinese-English Dictionary of Engineering Terms* (新编华英工学字汇), which was also one of the first specialized dictionaries published by Chinese engineers.[36] The formulation and implementation of industrial standards also needs to be mentioned, in which the CIE made an important contribution. In the 1930s, all the electricity-generating equipment used in power plants in dozens of large and medium cities in China were from several different foreign countries, such as the United States, Britain, Germany and Switzerland.[37] The

[36] 方厚枢：中国辞书编纂出版概况，中国出版年鉴，北京：商务印书馆，1980年12月。Fang, Houshu: Overview on Chinese dictionary compilation and publication. China's publishing Yearbook, Beijing: Commercial Press, December 1980:132.

[37] For example, the voltage of the power plants built in the United States for 110 V 60 Hz, Russia to build power

consequent problem was the different power transmission voltages and frequencies in various power plants. To solve this problem, CIE member electronic engineer Yun Zhen (恽震), together with another engineers in the CIE, had a brainstorming discussion and symposia, finally choosing the European standard in consideration of resource development. In 1954, the new standard of electricity formulated by Yun, together with several other power experts, became the first national standard in the PRC.[38]

Through starting the process from scratch, Chinese engineers became an independent occupational group separate from the traditional Chinese intelligentsia. The characteristics of the engineering profession, the preliminary engineering education system, group organization and group consciousness gradually formed with the development of industrialization following the Western model of development. However, in 1949, major reform was a turning point for both the politics of China and the fledgling professional engineers. After 1949, with the constant military retreat of the nationalist forces, domestic engineers had to make difficult choices: Some of them chose to move to Taiwan, such as Ling Hongxun (林鸿轩) and Shen Yi (沈毅), and some chose to emigrate, such as Gu Yuxiu (顾毓琇)and Weng Wenhao (翁文灏). However, most of engineers, as represented by bridge engineer Mao Yisheng (茅以升), chemical engineer Wu Chengluo (吴承洛), and civil engineer Zhao Zukang (赵祖康)[39] chose to stay in the Chinese mainland and joined the new regime to serve the construction of the new China.

2.1.2 Formation period of Chinese engineers occupational framework, 1949-1965

The social and economic situation was not optimistic in the early years of the PRC.

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plants for 110 volt 25 Hz, the construction of power plants in Japan is 110 V, 50 Hz, and the German power plants are built with 125 volt 25 hertz. And the United States and Europe in general user using the voltage are also varies, USA using 110/190 volts, while Europe uses 220/380 volts. See details on Gu Mengjie: “History of Chinese standardization Revisited”, “Chinese standardization”, 2001 3.

[38] 恽震：电力电工专家恽震自述(一)，中国科技史料，2000 年第 3 期。Yun Zhe: Electrical power expert Yun Zhen (Ⅰ)，“Chinese Science and Technology Historical”, 2000 No. 3: 197.

[39] Li,Xuetong, Weng, Wenhao Chronicle, Jinan: Shandong Education Publishing House,2005,10.

From the perspective of the social and economic structure, after almost one hundred years' development, Chinese modem industrialization still lagged behind and China was still an underdeveloped agricultural country. Just before the establishment of the PRC, Chinese industry as whole only contributed 15.5% of the gross value of the national industrial and agricultural output, with heavy industry taking only 4.5% (Table: 2.2). From an international perspective, the PRC was established during the Cold War. On the one hand, the PRC obtained support and recognition from the Soviet Union and the various peoples' states in Eastern Europe. Mao Zedong was determined to put the Soviet Union and the peoples' democratic countries in Eastern Europe in first place when handling external relations based on the international and the domestic situation of the time. First, China allied with the Soviet Union with the signing of the "Sino-Soviet Treaty of Friendship, Alliance and Mutual Assistance" together with two other agreements. The close alliance with the Soviet Union was actually the footstone for China to develop foreign relations. China received complete sets of factory equipment and aid through products from the Soviet Union. In this way, the leading position of heavy industry was reinforced.

However, the lack of scientific and engineering personnel became a major problem during the process of industrialization in China. There were not sufficient engineers and technicians to cater for the industrial development of the new period. Taking the largest Anshan Iron and Steel Enterprises for instance, in 1949 there were 70 engineers in the company, where 62 of them were Japanese engineers who stayed on due to the continuation of the project or before the expiry of their employment. According to the relevant Chinese statistical data, after the Japanese engineers had been sent back to Japan, the proportion of engineers in the Northeast, which was the nation's iron and steel center, had been reduced to 0.24% compared with the total engineers in the whole industry.[40] Therefore, we can see that Chinese engineers in the early stage after the establishment of the state were not characterized by the capability or strength in numbers to complete

[40] 中国社会科学院，中央档案馆：中华人民共和国经济档案资料选，1949-1952，综合卷，北京：中国城市经济社会出版社，1990。CASS & Central Archives: Economy Selected Archives in People's Republic of China, 1949-1952, comprehensive volume, Chinese urban economic and society Press, 1990:46.

large-scale projects independently.

To solve these problems, the CCP made reforms in several aspects, as follows.

Table 2.2 Comparison between China, USA, and India in terms of the critical industrial products in 1949

Product	Unit	Output of China	America		India	
			Output	Multiple	Output	Multiple
Coal	Billion tons	0.32	4.36	13.63	0.32	1
Oil	Million tons	12	24892	2074.33	25	2.08
Electric	Billion degrees	43	3451	80.26	49	1.14
Steel	Ton	15.8	7074	447.72	137	8.67
Iron	Million tons	25	4982	199.28	64	6.56
Cement	Million tons	66	3594	54.45	186	2.82

Source：中华人民共和国国家经济贸易委员会：中国工业五十年(第一卷)， 中国经济出版社，2000 年。People's Republic of China State Economic and Trade Commission: Fifty years' development of Chinese Industry (Vol. I), China Economics Press, 2000:9.

2.1.2.1 National science & technology policy

Science and technology institutions were established in the PRC through successive explorations, under fragile conditions in the early stage after the establishment of the state. Article 43 of the "Common Program of Chinese Peoples' Political Consultative Conference", published in the initial days of the PRC, included the most formal statement ever made by the PRC regarding the target of the development of science and technology. "It is necessary to develop the national science to serve the industry, agriculture and national defense. Also, it is necessary to encourage scientific discovery and invention, and to strengthen the spreading of scientific knowledge."[41] In fact, based on the firm understanding of the externalism of science and technology, Chinese leaders already had a rough idea of the roles to be played by science and technology in the new society. However, when the idea was planned to be turned into a program of action, due to the lack of technological talents in the CCP or maybe because the task of developing science and technology hadn't been brought onto the agenda, people couldn't find anything in the

[41] Common Program of the Chinese People's Political Consultative Conference

various government documents regarding the planned development of scientific and technological ideas.

From June 20-26 of 1950, the first Administrative Affairs Meeting of the Chinese Academy of Sciences was held in Beijing. More than one hundred scientists and engineers participated in this conference, while some of the leaders of the Communist Party and the government also gave speeches. It was the first national conference ever held in scientific and technological circles at the beginning of the PRC. Moreover, in the final report made by neurophysiologist Feng Depei (冯德培), who was the representative of Biology Group B, the planning and collectivity of scientific research was mentioned. He said that "in the past, due to the corrupt and reactionary political domination and the changeable situations, in the science circles, none of us ever dared to mention a long-term based research plan, or any large-scale research plan. However, things will be totally different in the future. The scientists of new China would be free to take long views with great courage to re-plan our research. Comparing it to a war, the previous efforts made by us in the research would be just like the random guerrillas. Moreover, now under the centralized leadership of the Chinese Academy of Sciences, we begin to establish regular armies, ready for the large-scale positional warfare."[42] On June 14, the Culture Committee issued to the Chinese Academy of Sciences the "Instruction on the basic tasks of the Chinese Academy of Sciences", which was filled with the idea of "development in a planned way" from beginning to end. Therefore, we can understand that both the new government and the scientific and technological community had reached an agreement on such an idea.

From August 18 to 24, the Conference of Scientific Representatives was held in Beijing with more than 500 representatives from various regions across China participating in the meeting. One of the remarkable achievements made in this conference was that the various dispersed and standalone research that were "studies for academic purpose", were consolidated into scientific work led by a unified organization to serve the people. That is

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[42] 陈伯达：在中国科学院研究员学习会议上的讲话。北京：人民出版社。1952。Chen, Boda: Speech at the Chinese Academy of Sciences researchers learn Meeting Beijing, People's Publishing House.1952.

to say, it would be an organized scientific work undertaken in a planned way.[43]

In August of 1952, Mao Zedong announced that: "After two years and a half's hard work, now the national economy has recovered and begins to enter into the period of planned construction."[44] Moreover, from September of that year, China entered into the primary stage for the formation of a planned economic system with the State Development Planning Commission starting to prepare the "the first Five-Year Plan". At the same time, scientific research was gradually included in the plan, which was a significant change.

In order to cater for such a change, in October 1952 the Chinese Academy of Sciences organized an enlarged presidential meeting, where the "Resolution of Chinese Academy of Sciences on strengthening study and introducing the Soviet Union's advanced science" was made, deciding to organize a delegation to visit the Soviet Academy of Science for the purpose of studying their advanced experience in scientific work. After the delegation returned, geologist Wu Heng (武衡) gave a particular report on the scientific and planning work of the Soviet Union which stated that the scientific work of the Soviet Union was characterized by extremely high planning. In terms of the particular operation, the Soviet Union had first planned scientific work based on the plan of the national economy and the necessity for the development of the theoretical science. It had also focused its attention on the most promising and revolutionary aspects that developed the quickest, which were also called the "growing points" of science by the Soviet scientists. Focusing on the growing points of science meant concentrating energy on solving critical problems during the development of current science. Therefore, it was unnecessary to equally research every aspect of the sciences and the various disciplines of science. By researching or solving critical problems during the development of science, a series of other problems would be solved incidentally, or a new scientific direction would be found. All of these

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43 薄一波：若干重大决策与事件的回顾（上下册），北京：中共党史出版社，2008.1。Bo,Yibo: Review about several major decisions and events of CCP, Beijing: Chinese Communist Party History Publishing House, 2008.1:499-500.

44 林烷芬：我国计划经济体制的基本形成及其历史特点。党的文献，1995(2)。Lin Wanfen: Characteristics of the formation and history of planned economy in China. Literatures about China Communist Party.1995(2).

options and practices from the Soviet Union were "advanced experiences" fresh to the Chinese science and technology circles of the time, who were significantly influenced by them. They were widely applied in the formulation and execution of the various technical plans or programs made by the PRC.

Although we could refer to the Soviet experience, it was still necessary for the Chinese to complete lots of works before we could work out feasible plans to guide Chinese scientific development. Actually in October 1953, based on the "Report submitted to the Central Committee on the basic situation of the current work and the following works and tasks to be done by the Academy of Sciences" submitted by the Party Committee of the Chinese Academy of Sciences to the Central Committee 17, it was suggested that the Central Committee should take measures to improve the leading methods to "secure the smooth completion of the scientific works and tasks so that the scientific work will serve the state construction effectively."[45] On March 8 1954, based on the written instruction made by the Central Committee to the "Report", it stated explicitly that "the State Planning Commission takes the responsibility to review the plans for the Academy of Sciences, the production department and the institutions of higher education in terms of their scientific research for the purpose to solve the problems arising from the combination of scientific research and the production practices and the issues in all aspects regarding the assignment and cooperation during the scientific research."[46]

During this period, the CCP had a better understanding of the science program that was "compliant with a general principle to start from the needs of the state."[47] In such a system, all of the scientific and technological activities would ultimately be governed under the unified leadership of the government with administrative measures having been taken by the state to create a unified arrangement on various scientific and technological resources for the purpose of promoting scientific and technological progress by means of

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45 薛攀皋: 中国科学院史事汇要(1953).中国科学院院史文物资料征集委员会办公室，1996.6。(未出版) Xue,Pangao: History of Chinese Academy of Sciences Department (1953). Historical data collection committee office, CAS, 1996.6. (Unpublished).

46 人民手册(1949-50),1957 ,People's handbook,1957:583.

47 To develop a good plan. Chinese Science Bulletin,1955.

planned management. For the major scientific projects, various forces would be organized to tackle critical problems through collaboration.

Upon the establishment of the PRC, the CCP brought the problems of industrialization and modernization onto the agenda. In 1953, China began to implement (1953-1957) the first Five-Year Plan for the development of the national economy. It concentrated the main forces of the economy on developing heavy industry for the purpose of establishing a basis for national industrialization and the modernization of national defense, whilst also training the corresponding technical personnel, developing the transportation industry, light industry, agriculture and expanding commerce. The plan also estimated that in the following five years the total expenditure on national economic construction and cultural and educational development would be RMB 76.64 billion with RMB 42.74 billion to be invested in capital construction, meaning investment in capital construction would account for 55.8% of total expenditure.[48] As the key point, industry would take 58.2% with 7.6% for agriculture, forestry and water conservation, 19.2% of transportation and posts, 3% for trade, bank and material reserves, 7.2% for culture, education and sanitation, and 3.7% for urban public utilities. The total expenditure listed above was equivalent to 0.7 billion taels of gold.[49] Such a large-scale state construction with so much investment was unprecedented in the Chinese history .

The second Five-Year Plan for national economic development during the period 1958-1962 was first proposed at the Eighth National Congress of the Chinese Communist Party held in Beijing, September 15-27 1956. Zhou Enlai made a report on this draft at the eighth congress, where he proposed that, if possible, the development rate of the national economy should be set reasonably as needed and the plan should be made on a positive, stable and reliable basis to secure the balanced development of national economy. Therefore, five primary tasks were stipulated in the second Five-Year Plan: (I) Continue to carry out industrial construction centered around heavy industry to push the technical

[48] 2.355 yuan =1 dollar

[49] 董辅礽：中华人民共和国经济史。经济科学出版社，1999 年。Dong, Fureng: Economic History of People's Republic of China, Economic Science Press, 1999:74.

transformation of the national economy forward and lay a solid foundation for Chinese socialist industrialization; (II) Continue to complete the socialist transformation of society so as to reinforce and expand collective and state ownership. (III) Further develop production in industry, agriculture and handicraft industry based on the development of infrastructure and the continuing socialist transformation, and push forward the corresponding development of transportation and commerce. (IV) Make every effort to train construction personnel and strengthen scientific research to cater for socialist economic and cultural development. (V) Strengthen the defense forces and enhance the standards of people's material lives on the basis of the development of industrial and agricultural production.

However, the plan was completed as a draft without any specific implementation programs published or executed. After the approval of the general line for socialist construction at the Second Plenary of the 8th National congress of the CCP, the wave of Great Leap Forward movement had spread across China in various regions and industries with the original planned indicators having been revised or increased impractically. The slogan of "taking steel as the key link" was then proposed in industry, to continuously shorten the time for steel production so as to "surpass England, Catch Up with the United States". Moreover, in agriculture, the slogan of "taking grain as the key link", publicized the fact that "as long as people wanted, they would determine crop production". Therefore, bogus reports and fabrications were made in various regions across China with boastfulness prevailing all the time. By 1962, the disproportion in national economy was so severe that agricultural production was damaged severely with a significant decrease in the manufacture of light industry, with the Party and Chinese people encountering the most severe economic difficulties since the establishment of the state. On account of this, there was no other way out but to adjust the national economy in the following three years. Frankly, due to the impact of the Great Leap Forward the effect of the implementation of the second Five-Year Plan was negligible.

However, a twelve years' plan for science and technology made by Chinese government during the middle 1950s was successful. In 1956, one of the tasks faced by

China was to quickly develop the economy, science and culture to build a powerful socialist country. Such a large-scale construction mission placed an urgent demand on science and technology, requiring the rapid development of science and technology to make a greater contribution to the development of the national economy. Zhou Enlai has pointed out that "compared with any other time in the history, the need to enhance the production technology significantly is required more than ever in the socialist era. And the state needs to give full play to science and utilize the scientific knowledge."[50] In January 1956, Zhou Enlai declared that the State Council had begun to organize and develop the first long-term plan in the development of Chinese science and technology, "The perspective, long-term plan on science and technology development from 1965 to 1967". He also gave definite instructions on the general guidelines and requirements for the plan: "When working out this perspective long-term plan, if possible and when necessary, make sure to introduce as quickly as possible the most advanced scientific achievements made in the world to Chinese science division, defense department, production department and education department, and supplement as soon as possible the categories lacked in the Chinese science circles but urgently needed by the state construction to make sure that 12 years later, Chinese scientific and technological level of these types will be very close to that in the Soviet Union and the other great powers."[51] On Januray 31 1956, Chen Yi (陈毅) and Li Fuchun (李富春) convened the leaders of the various departments in the state council and around 1,000 Chinese science and technology experts, who had participated in planning work, to make an accurate arrangement on the development of a "12-Year science and technology plan", in terms of its significance, guideline, contents and requirements.

In December 1956, the "Report made to the Central Committee on the scientific planning work" and the "Outline of the perspective long-term plan on the science and technology development from 1965 to 1967 (amended draft)" were endorsed by the CCP

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[50] 建国以来重要文献选编（第8册）。中央文献山版社1994年版，第13页.Selected literature PRC. Vol.8, Central Literature Publishing House.1994:13.

[51] 关于知识分子问题的报告,周恩来选集下卷。人民出版社，1984 年第一版，第 180 页。Report on the issues of intellectuals, Zhou Enlai anthology volumes. People's Publishing House, 1984 edition:180.

Central Committee, the plan confirmed the planning principle of "discipline led by task" (任务带学科), which aroused great disputes during its formulation. One of the opinions held that planning should be made according to the task, which also meant that plans must be developed according to the scientific and technological tasks required by economic construction. However, one of the opinions held that plans must be made according to disciplines. The CAS dean counselor, Lazarenko from the Soviet Union, introduced planning methods used by the Soviet Union, which were based on mathematics, physics and biology, etc. With the combination of said methods, Du Runsheng from the CAS proposed a principle, which was "task as the longitude and discipline as the latitude to let discipline led by mission". However, some of the experienced scientists, especially those who had been engaged in fundamental research, still had a different opinion. Their concern was that such a method might neglect basic research. Meanwhile, they raised a question about what would be done if the task failed to lead discipline. These items were finally reported to Zhou Enlai, who instructed the adding of Task 57: "Research on some fundamental theoretical problems in modern natural science" as one of the critical tasks to reach an agreement, in addition to the 56 major scientific and technical works originally planned.

On account of the needs of every aspect of economic construction in the next 10 years or so, the plan suggested 57 tasks, which were "valuable, comprehensive and nation-based on a long time basis" and at the same time "called for the cooperation between various science divisions for a solution and required the relevant departments and scientists to put them at the first place and complete them through joint efforts." However, the plan also held that in order to realize all-round development, it was necessary to grasp particular problems of critical importance and solve them purposely under the current situation of insufficient manpower. In fact, after the "12-Year scientific plan" was developed, a series of extraordinary measures were taken successively to implement and realize the targets and tasks regulated by the plan. The most important was that four major emergency steps have been worked out and executed, including emergency measures for the development of computing technology, semiconductor technology, radio electronics, automatics and remote control technology, which were the four new technologies that were vigorously developed internationally at that time and would push forward the whole of science and technology.

After seven years' of efforts, significant changes had been made in every aspect of Chinese science and technology, with the following outstanding achievements having been made: Geological work involving more than 130 mineral resources, especially oil. With demonstrations made of the new petroleum geology, besides some newly discovered large oil fields such as Daqing Oilfield, the verified reserves in the vast territory of China had significantly exceeded the goal preset in the "12-Year scientific plan". In terms of industrial science and technology, at that time Chinese engineers were capable of designing and constructing by themselves major projects for economic construction, including integrated iron and steel works with an annual yield of 1,500 thousand tons, an oil refinery with annual yield of 50,000 tons, a hydroelectric power plant with the installed capacity of 650,000 kilowatt and an electrified railway, etc. In terms of emerging technology, China was also capable of producing certain experimental facilities for the research of nuclear physics, such as the synchro accelerator, etc. Moreover, radioisotopes had been applied to research and experiment in industry, agriculture and medical science. With the self-design and manufacture of electronic digital computers and other types of electronic computers, a computing center had also been set up to solve numerous problems regarding computation that could hardly been tackled by manpower during the research and design of a national economy and national defense construction. Meanwhile, achievements had also been made in automation technology, semiconductor technology, radio and electronic technology. Therefore, after seven years' hard work, China had succeeded in improving its scientific and technical level from that of an extremely underdeveloped level to the international level of the 1940s.

2.1.2.2 Utilization of technical and engineering personal

In the process of transformation, the Chinese communist government has shown a keen awareness of the need to recruit engineering manpower. In the early established PRC, the CCP recruited engineers mainly in the following ways:

1. The acquisition of scientific and technological employees from the Nationalist Government. They were the main force during the construction of the PRC. According to an instruction from Mao Zedong, "Please be well aware that besides the manager and workers' representative, the management committee must include technicians, engineers, and other employees. Such a committee must be a management committee under the system of overall responsibility by factory manager. Under any circumstances, besides the company director or manager who must be attached with great importance, the technicians, engineers and employees with sufficient knowledge and experiences must receive significant attention as well. If necessary, no matter how high the salary might be, they must be employed as well when it becomes possible, even if they are the members of the KMT ."[52] They became the first manpower to construct China.

2. The upsurge of overseas students' returning to China in the early 1950s. According to the preliminary estimation made by the Ministry of Education, as of August 30 1950, there were 5,541 students studying in foreign countries, with 3,500 of them in USA, 1,200 students in Japan, 443 students in England and some in other countries. In terms of majors, those that specialized in science, engineering, agriculture and medicine accounted for 70%.[53] In fact, the mass of overseas students returning lots of information in connection with the modern technical revolution to the forefront of domestic science and technology, and the latest and most advanced scientific knowledge, methods, technology, information and expertise in scientific organization and management from the West, played a critical role in working out the correct plans and choosing the research direction of the development of science at that time.

3. The enrolled engineering students that would graduate from universities. According to the statistics from the Ministry of Education under the Chinese Nationalist Party government, in 1947 there were 207 universities and colleges, with 155,036 enrolled

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[52] Mao, Zedong: Selected Works of Mao Zedong, Vol. 5. Beijing: People's Publishing House,1996:88.

[53] 金铁宽: 中华人民共和国教育大事记（上册）。济南：山东教育出版社，1995。Jin Tiekuan: People's Republic of China Education Events Ⅰ. Jinan: Shandong Education Press, 1995.

students, among whom the students of engineering were around 17.8% of the total.[54]

However, the number of engineers and technicians could not match the fast pace of industrial construction. When China published its Five-Year Plan in the middle of 1955, the document stipulated: "The ranks of workers in the various fields, the national economy, and the state departments will, in this 5-year period, need to be augmented by about 1 million additional specialized personnel graduating from the various institutions of higher education and secondary schools. The departments of industry, transport, agriculture, and forestry under the central authorities need to be reinforced by about 1 million additional skilled workers."[55]

During the first Five-Year Plan, there was a substantial increase engineers and technicians employed in the industry. Zhou Enlai, in a report to the first session of the Second National People's Congress said: "In 1957, industries throughout the country employed 175,000 engineering and technical personnel, a threefold increase compared with 1952, when the number was 58,000."[56] In 1958 a Chinese economist, utilizing the experiences of the Soviet Union, made an estimate that during 1956-1957 period, China would need to have 8 million to 10 million new specialists graduate from college or secondary vocational schools.[57] However, due to the period (the estimate was made during the Big Leap Forward) the statistics were surely inflated. In January 1960, Chang Qichun, the director of the staff office for culture and education of the State Council, claimed that:

"We have now a force of about 1 million engineering specialists, including both higher and medium-level specialists. However, this force is still not adequate to meet the need created by the speedy development of our industrial construction. During the last three years of the Second Five-Year Plan and the entire period of the Third Five-Year Plan, we have to train several million more engineering specialists to meet the requirement of the

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[54] Edit by Republic of China Ministry of Education, Chinese education Year book 1948 No.4,Shanghai Business Publishing House.1948.

[55] First five year plan for Development of the National Economy of the PRC,1953-1957 .Beijing:Foreign languages Publishing House ,1956:176.

[56] Xinhua Banyuekan, New china semimonthly ,No.9,1959:3.

[57] Zeng Wenqing,The socialist Industrialization of China, Beijing: Renmin Ribaoshe,1958:237.

country's industrial construction."[58]

2.1.2.3 Training programs for engineers

To meet the needs of the economic development programs for technical personnel, engineering education reform had been put on the agenda by the CCP government. Before 1949, higher education in China had been an elite education. However, due to the social turmoil of modern China the nation was weak, and people were impoverished. Most of the families could not afford higher education, leading to a small number of cultivated talents. However after 1949, learning from Soviet Union in a comprehensive way allowed Chinese higher engineering education to be transformed from an elite education to a mass education. Universities made a commitment to train the specialists necessary for the management of a modern industrial society, instead of any well-learned elite person. The government had also taken corresponding measures to guarantee that the mission of education "popularization" would be carried out. First, it removed private universities from the system to make higher education public. Meanwhile, by means of taking over, and the adjustment and transformation of the early 1950s, all of the departments and faculties in private universities were subsumed into the public schools, leading to the end of the private university in China.

Second, the government paid all of the expenses for higher education, making the institution of higher education a public institution in nature with all of the funds obtained from the government and no tuition fees for students. Moreover, when the students received access to higher education, they not only received subsidies from the government, but also were assigned to works in a unified way by the government when they graduated. In addition to this, Chinese higher education in this period was also characterized by the fact that it did not implement the academic degree system. Therefore, when students graduated they were only granted graduation certificates indicating the school of graduation, major and date. It was awarded to a graduate of a two-year regular college as well as to an individual successfully completing a five-year course in a technical institute.

[58] Hongqi, Red Flag,No.3 1960:11.

Despite the significant difference in the length between the 2, 3, and 5-year graduates, for the most part this study discusses "graduates" rather than holders of particular degrees.[59]

To be more precise, the Chinese engineering education system was divided into three levels:

A. Regular training programs for engineers. Starting from 1951, by learning from Soviet experiences, Chinese higher education experienced a "large-scale adjustment of departments and faculties" (院校调整)[60] with the guideline as follows: "Focus on the cultivation of engineering and construction talents and qualified teachers to develop various professional institutes, reorganize and strengthen the comprehensive universities" and "There are two kinds of professional institutes and schools, the multidisciplinary and the single-subject schools with the central mission targeted to train various occupational and senior engineers."[61] Therefore, the primary purpose of university was to prepare scientific and research talents and qualified teachers for secondary school and institution of higher education. According to the pattern of Soviet colleges and universities, the industrial, agricultural, teaching and medical departments would be separated from the original universities or they would be established separately or merged again to act as the corresponding individual institutions or colleges in diversified forms to cater to the needs of various professional talents required by state construction.

The Chinese higher education system was established in reference to the centralized management of higher education, the state-owned higher education system and the highly specialized education system of the Soviet Union. The Chinese government began to apply central and unified plan management to colleges and universities. The following areas were covered in the range of government's planning management: College enrollments, majors, appointments, school register management and curriculum setting,

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59 Chen, Chuyuan: Scientific and Engineering Manpower in Communist China 1949-1963, Institute of Far Eastern Studies Seton Hall University, South Orange, New Jersey.1965:36.

60 Also called educational reform in 1950s.

61 张光斗、王冀生主编：中国高等工程教育，北京：清华大学出版社。1995。Zhang Guangdou & Jisheng Wang eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:124.

etc. With the adjustment of departments and faculties, China had established a higher education system with comprehensive universities, multidisciplinary polytechnic universities and specialized institutions set up separately. The various Chinese colleges and universities built before establishment of the state were reduced from 207 to 182 schools and comprehensive universities reduced from 55 to 14. There were 168 specialized institutions, which accounted for 84% of the total colleges and universities with engineering colleges increased from 18 colleges before the founding of PRC to 39 colleges.[62] From the perspective of the school system, the significant changes in the number of the comprehensive universities and special institutions meant that engineering colleges became independent from comprehensive universities to realize adjustment goals for the development of particular institutions with the training objective transformed from the Anglo-American model of "liberal education" during the Republican period to "specialized education" for the purpose of "training various professional and senior engineers".[63] In fact, after the first Five-Year Plan was completed in 1953, the enrollment of students majoring in engineering technology quickly increased, and many engineering colleges were quickly set up as well. The total number of first-time enrollments for 1953-1957 was expected to be 543,300. In the academic year 1957-1958, the concluding one of the 5-year period, the planned number of students to be enrolled was 434,600, more than twice the reported total for 1952-1953. 41% of the students majored in engineering.

However, with the convening of the 20th Congress of the Soviet Communist Party and due to some political and military conflicts between China and the Soviet Union, the relationship between China and the Soviet Union turned cold after 1956. Moreover, various problems that arose during the early construction period made the leaders of the Central Committee of the Chinese Communist Party treat the experience of the Soviet

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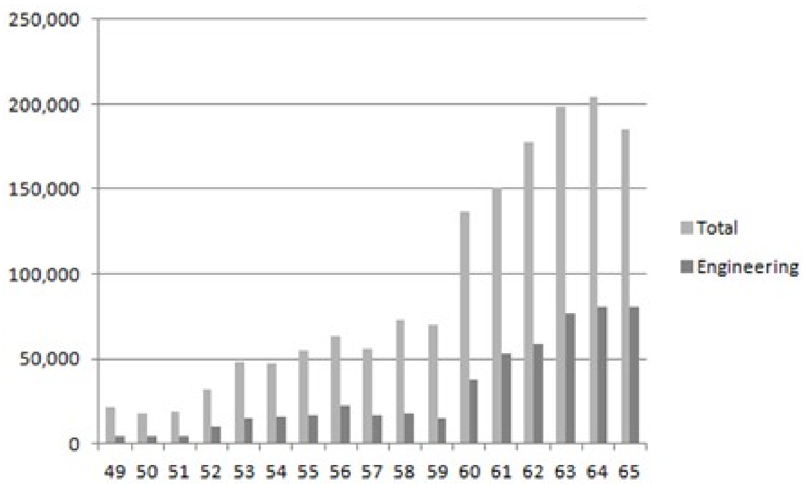
62 People's education 人民教育。No 1,1953: 14.

63 张光斗、王冀生主编：中国高等工程教育，北京：清华大学出版社。1995。Zhang Guangdou & Jisheng Wang eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:124.

Union more rationally. They no longer had blind faith in the Soviet Union, and China began to reconsider its higher engineering education with some adjustments having been made in certain aspects of it.

Then, with the development of the 'Great Leap Forward' movement after 1958, a huge educational revolution centered on the combination of education and productive labor spread across China. In fact, in 1957 there were only 229 colleges and universities in China, while in 1958 the number soared to 791. Particularly in 1960, the number of the national colleges and universities increased sharply to 1,289 with enrollments in ordinary universities increasing from 106,000 in 1957 to 265,000 in 1958. Even in 1960, enrollments rose to 323,000, which was more than the number of the high school graduates, around 288,000. The number of the engineering colleges especially soared, up to 472 with the number of enrolled students up to 388,769.[64]

Figure 2.1 Numbers of engineering graduates [65]



In 1961, with the implementation of the guideline for, "adjustment, reinforcement, enrichment and improvement", and the execution of the "Interim Regulations on the colleges and universities directly under the Ministry of Education (Draft)" (called "60 Provisions for colleges and universities" 高教六十条for short), those practices taken

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64 潘懋源编：中国高等教育。广州高教出版社。2003。Pan, Maoyuan ed.: Chinese Higher Education. Guangzhou : Guangdong Higher education Publishing House,2003:359.

65 Data Analysis is based on Chinese Educational Achievement Statistics, 1949-1983; Chinese Ministry of Education Planning and Finance Division. People's Education Publishing House.1984: 90-93.

since 1958 which violated the laws of education were corrected and the hierarchical structure of higher education was adjusted as well. It further defined that the training objective of higher engineering undergraduate education was to cultivate "the professional personnel for socialist construction", emphasizing that students must "complete the necessary training for a technician from the perspective of academic study when they study in the universities."[66] Undergraduate study in engineering would require the students to study for five years, except for a handful of universities that required four years or six years.

B. Advanced study in foreign countries. Besides the training of domestic technical specialists, one of the most feasible methods of training was to send students abroad for further study. This practice, followed by the Nationalist government, was continued under the Communist regime. However, the CCP took the recognition of ideology and the social system as the first factors to be considered. Therefore, the main countries for foreign study changed from England and USA to the socialist countries led by the Soviets. From 1951 to 1965, through selection, the Chinese government sent almost 10,000 students to nations including Romania, Poland, Czechoslovakia, Bulgaria, Hungary and GDR; and, of course the Soviet Union, where 8,424 students were dispatched to study.[67]

According to Table 2.5, we find that more than half of the students selected to study abroad were engineering students. Moreover, 1954-56 was the period during which the largest number of students were dispatched to study abroad, which was in accordance with China's rather good relationship with the Soviet Union. However since 1957, due to the international conflict between the Soviet Union and Poland as well as the impact of the domestic political movement, the number of students dispatched abroad dropped sharply, although engineering students still took a proportion of around 41%.

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[66] 张光斗、王冀生主编：中国高等工程教育，北京：清华大学出版社。1995。Zhang Guangdou & Jisheng Wang eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:126.

[67] Source：Data Analysis is based on Chinese educational achievement statistics1940-1983. Chinese Ministry of Education Planning and Finance Division. People's Education Publishing House.1984:126-136.

Table 2.3 Percentage Distribution of engineering students by Subfield of study

Year	Total	Applied Geology	Mining	Power Engineering	Metall-urgy	Mecha-nical enginee-ring	electrical machines instruments	Radio electro-nics	Chemical Engineeri-ng	Grain Processing food	Light Industry	Mapping Surveying Hydrology	Civil Engineering Architecture	Transpo-tation	Telecommu-nication	Others	Unclassi-fied
1953	100	10.28	8.68	7.54	3.57	20.63	1.97	0	3.84	0.19	2.61	1.83	23.64	2.45	0.88	8.11	3.76
1954	100	10.38	8.58	6.82	4.49	23.33	2.59	0	5.13	0.54	2.95	2.44	20.34	1.73	0.8	9.88	0
1955	100	7.9	7.72	6.8	4.82	26.38	3.94	0	5.03	0.58	1.75	2.31	16.26	2.75	2.01	11.75	0
1956	100	10.16	5.94	6.4	3.42	26.05	6.44	0	4.85	0.78	1.43	1.79	14.95	3.42	1.77	12.6	0
1957	100	7.37	8.06	8.47	3.57	24.22	8.15	0	5.54	0.85	2.23	2.08	18.9	2.59	1.75	6.22	0
1958	100	6.23	7.58	6.14	6.64	25.61	4.15	2.8	12.07	0.96	2.61	1.14	14.67	2.23	1.69	5.07	0.41
1959	100	5.61	7.41	6.55	6.59	24.61	3.87	3.38	10.07	0.81	2.81	1.27	14.36	2.43	2.15	6.84	0.34
1960	100	4.91	6.59	6.92	5.94	23.54	4.19	7.53	10.61	0.83	1.98	1.14	14.67	2.23	1.69	5.07	0.41
1961	100	5.33	8.39	5.61	4.78	25.36	3.79	7.43	10.97	0.62	1.52	0.99	9.4	2.39	1.43	11.92	0.07
1962	100	4.04	8.26	5.65	5.5	28.6	4.84	7.19	10.51	0.97	1.98	1.42	7.66	2.66	2.21	8.51	0
1963	100	3.66	7.21	6.84	3.96	31.25	4.04	5.91	9.54	1.19	2	0.93	9.34	2.62	2.27	9.24	0
1964	100	3.8	7.3	6.8	4.6	31.9	3.5	6.1	8.7	1.3	1.8	0.9	10	2.2	2.2	8.9	0
1965	100	3.9	6.5	6.7	3.8	31.9	3.2	6.1	7.7	1.1	1.9	0.8	9.6	2.3	1.9	12.6	0

Source: According to the statistics on the achievements made by the Chinese Education 1949-1983, prepared by the Planning and Financial Department under the Ministry of Education of PRC, People's Education Publishing House.1984:92-93.

After 1959, due to the significant change in the relationship between China and the Soviet Union, the difference in ideology between the two parties had evolved into a conflict of national interests. The significant changes in the entire international situation, the shift of study-abroad guidelines and the changes in particular study-abroad policies very much interfered with work related to studying in the Soviet Union in the 1960s. The biggest sign of this was that the number of students studying in the Soviet Union had dropped sharply. In fact, during this period, the main part of the students studying in the Soviet Union was no longer university students. Instead, they were teachers engaged in further study with a shortened study period and with majors in connection with non-key industries or language translation, etc. However, due to the impact of the Great Cultural Revolution, the work of selecting and dispatching students to study abroad was discontinued entirely in 1966. .

After returning to China, those students who had studied in the Soviet Union played an invaluable role in various fields of New China, whilst also alleviating the shortage of Chinese engineers and technicians. Especially after Soviet experts had withdrawn from China, these students assumed a high responsibility for the national defense of the PRC, the military and nuclear industries and some other construction tasks. They were called on as the power source when the PRC ship ploughed ahead at full speed, with their names consistently found in the lists of participants in major national projects. Some of them became the leaders of the Party and heads of state, while more than 200 of them became the leading cadres at ministerial levels.

C. Specialized training programs for engineers. During this period, a feature that fluctuated greatly characterized the development of Chinese higher engineering education. To be specific, the high fluctuation was found in the development of professional higher engineering education. In 1949, there were 30,320 enrolled students in the nation with 7,202 of the enrolled engineering college students, which accounted for 23.7% of the total students. In order to meet the urgent demand of the large-scale economic construction of the first Five-Year Plan, the CCP decided to set up special two-year courses at the engineering colleges for the purpose of cultivating "advanced engineers". By 1953, of the 34,165 enrollments in national engineering schools, 10,880 students were enrolled in technical secondary schools, accounting for 31.8% of the total students. Accordingly, the number of the nationally enrolled engineering students was 79,970 with 25,748 of them enrolled as junior college students, who made up 32.2% of the total.[68] However, because the state considered such a "special course" as a temporary measure to solve the problem of insufficient technical cadres at that time, with the strengthening of secondary industrial and technical schools, those particular course enrollments began to decrease gradually from 1955. By 1957, the proportion of national engineering college students was reduced sharply to 0.1% of the total.

Before 1957, the CCP mainly relied on universities and colleges. However, after 1958, things were different. With the development of the Great Leap Forward movement in 1958 and based on the slogan of "walking on two legs", the technical colleges sharply expanded, as the CCP wanted to cultivate outstanding engineers in the shortest time through professional training. Hundreds of part-time universities and vocational schools sprouted across the mainland. In 1957, the numbers of vocational school enrollment and the enrolled students were separately just 42 and 1,025. However in 1960, both of the figures were sharply increased to 19,968 and 53,897 respectively, with a growth rate of 474.4 times and 51.5 times separately; this went far beyond the limit that the state could afford to take. Luckily with the implementation of the guideline, "adjustment, reinforcement, enrichment and improvement" (调整，巩固，充实，提高) in 1962, such a situation was corrected shortly. According to the Ministry of Education, "For those vocational schools established during the Great Leap Forward movement, except the batch characterized with good conditions, most of them should be transformed to be secondary technical schools"[69]; a lot of advanced engineering vocational colleges were

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[68] 张光斗，王冀生主编：中国高等工程教育，北京：清华大学出版社。1995 。Zhang, Guangdou & Jisheng Wang eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:129.

[69] 张光斗，王冀生主编：中国高等工程教育，北京：清华大学出版社。1995。Zhang, Guangdou & Jisheng Wang eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:127.

successively discontinued. By 1965, the number of enrolled engineering college students was again reduced, and was lower than 1% of the total enrolled engineering undergraduates and college students.[70] Meanwhile, part-time universities, which were also entirely different from the general universities, had been adopted by CCP. By the end of 1959, some 150 spare-time higher institutions existed throughout the country. According to the February 1960 directive of the CCP Central Committee and the State council, an Education Committee was organized to take charge of this program.[71] An official report in January 1960 listed the number of workers participating in spare-time higher education as 170,000.[72] Later reports placed this number at 370,000. By the end of 1960, 470,000 workers were reported to be enrolled in spare-time colleges,[73] which was about one-half of the total number of students enrolled full time in colleges and universities in the same year. Generally, spare-time universities and colleges were sponsored by the regular institutions of higher education or run by factories and enterprises. Most of the students enrolled in the spare-time schools were veteran workers, skilled in productive operations, who would not have qualified for this level of school work according to Western education standards. The term of study in the spare-time colleges varied from two to five years, with usually only eight hours a week course time. The teaching staff was usually composed of engineers and party cadres in the factories. Their quality was much lower than in regular colleges. After finishing their studies, most of these workers returned to their former posts, but many were promoted to engineers and others were assigned as teachers in spare-time secondary schools.[74]

To build up an army of engineering and technical personnel from the proletarian class, the CCP promoted a great number of skilled workers on the basis of their loyalty and obedience to the party. This new policy, as explained by Yang Xiufeng, was designed

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[70] 张光斗，王冀生主编：中国高等工程教育，北京：清华大学出版社。1995 . Zhang,Guangdou & Wang,Jisheng eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:127.

[71] Zhongguo Xinwen (China News Service), Feb.24,1960:4.

[72] Zhongguo Xinwen (China News Service), Jan.28,1960:8.

[73] Zhongguo Xinwen (China News Service), June,1960:7.

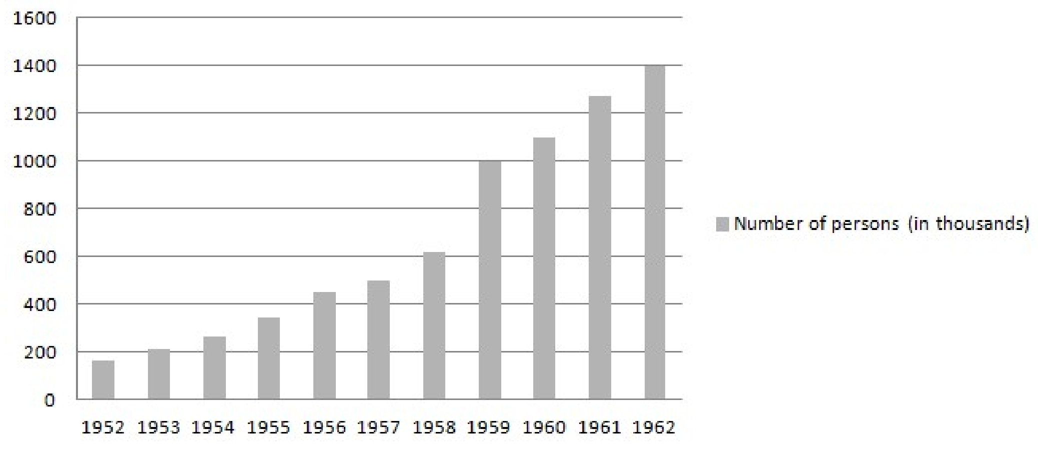
[74] Guangming Ribao Enlightenment Daily, Mar 9,1960.

to “discard the superstitious beliefs of the masses, to liberate their blind worship of a small number of experts, and to remove the mantle of mystery from scientific research work.”[75] Beginning in 1959, thousands of workers were raised to the rank of engineer or technician. Statistics compiled by the five important iron centers, Wuhan, Baotou, Taiyuan, Longyan and Shijingshan, show that a total of 146 engineers and 46 factory and mine directors were promoted from the ranks of workers in the first four months of 1960.[76] According to 1960 statistics for Gansu Province 28,000 workers from various enterprises were promoted to engineers and technicians.[77]

2.1.2.4 Employment of engineers

Official information on the employment of engineers in the PRC is extremely scant; the treatment of engineers and technicians was always confused. We can only find some clues from the state Statistical Bureau and some reports from the Central leadership. However, even with inaccurate numbers we can still work out that the number of engineers and technicians increased sharply during the 10-year period from 1952.

Figure 2.2 Engineers and technicians in the PRC by year and number, 1952-1962[78]



[75] Yang xiufeng op cite

[76] Yejin Bao, Metallurgical News,No.193 1960:4.

[77] Zhongguo Xinwen (China News Service),Feb.1,1961:4.

[78] Cheng, ChuYuan: Scientific and Engineering Manpower in Communist China,1949-1963,Washington D.C. 1965:111.

This data includes four major categories：

1. Professional engineers with at least the equivalent of a college diploma; the number is slight in the total.
2. Skilled workers who did not have a college education but who were promoted to engineers.
3. Technicians with college diplomas or a secondary vocational school education
4. Skilled workers with the title of technician.

From an academic point of view, according to the September 1955 census, of the 2.7 million professional and semiprofessional workers, only 1.2 million (45%) were educated in institutions of higher learning or secondary vocational schools.[79] This small level of education was remarkably reflected in the leading personnel of industrial enterprises. According to the census, there were 14,863 technical workers holding chief or deputy positions as industrial leaders, only 9 percent of whom had graduated from institutions of higher learning or specialized schools.

In fact, a nationally unified wage system was applied in China. In the early stage of its development, the CCP's wage standard was calculated based on the "work point" system, which was connected with five kinds of commodities, including food, clothes, edible oil, salt and coal. This was designed to protect the recipients against inflation. In 1956, the Ministry of Labor under the Central People's Government carried out a reform of the national wage system with the main contents including: Cancelling the salary distribution system and allowance system to uniformly implement a system where wage standard would be specified directly through money and the worker's wage bracket, and the coefficient of the wage bracket would be separately determined based on industries. The technical grade standard would also be uniformly revised to apply a hierarchical wage system that would be applicable to the enterprise leadership, engineers and employees based on their positions or titles. Meanwhile, workers in the local state-owned enterprises would be applied to a wage standard and wage system that would be worked out by various provinces, municipalities and autonomous regions according to the size of the enterprise, the equipment, technical

[79] Tongji Gongzuo Tongxin (Statistical Work Bulletin),No.23,1956:29.

level and the current wage status by referring to the wage standard and wage system applicable to the employees in the central state-owned enterprises.

In terms of regulations on engineer quality, the state had included technicians in the "state cadre" series for management by referring to the Soviet management pattern, where their positions were appointed just like the cadres of the party and government, and where technical positions were linked to wages, benefits, and remuneration, which would be available throughout their lives. As professional technicians, engineers were classified into 12 classes with each class featuring very strict requirements. As long as the conditions were met, the engineer would be appointed through the administrative method. These 12 classes separately corresponded to a hierarchical wage system. During this period, engineer was just a title (position) that was also a state cadre. Primarily, such a management pattern, integrated with qualifications, positions and wages, catered for the planned economic system. However in the early of the 1960s, due to financial difficulties, only the "title" of engineer was introduced without any connection to remuneration.

According to the book "Income and Standard of Living in Mainland China" by Cheng Chuyuan, the average wage of industrial workers was about 65 Yuan (2,355 Yuan =1 dollar) monthly under the 1965 reform (see table 2.5). The highest paid chief engineers were to receive about four times the salary of the average worker, 2.4 times that of average technical personnel and 1.4 times that of the average engineer.

Table 2.4 Monthly wages of engineers and technicians in Communist China since 1956 wage reform, by job title and wage class

Job Title	Monthly wage Standards		
	Class A	Class B	Class C
Director, deputy director , chief engineer	155-263	143-240	132-218
Deputy chief engineer, chief mechanic , chief designer,	135-223	133-200	128-190
Chief of the major workshop, chief of relevant section	115-181	108-169	99-158
Deputy Chief workshop, secretary to the director, section chief	103-152	96-143	89-133
Chief of work section	77-147	72-136	70-126
Engineers in responsible positions	118-181	117-169	116-158
Technicians in responsible positions	103-166	96-156	89-145
Technical personnel	64-102	64-102	64-102
Economists in responsible positions	103-166	96-156	89-145
Chief accountants, chief quota adjustors	74-126	73-123	72-109
Accountants, wage clerks, planning personnel	62-105	62-105	62-105
Statisticians, clerks for technical data files	50-89	50-89	50-89

Sources: Cheng chuyuan , income and Standard of Living in Mainland China,vol.I:124

Cheng chuyuan: Scientific and engineering manpower in communist China,1949-1963, Washington D.C. 1965:111.

Besides wages and salaries, engineers also received bonuses, and rewards. In 1954, the Chinese government worked out a rather particular policy, "The interim regulations on the awards for invention, technology improvement and rationalization proposal related to production", which was essentially made in accordance with the Soviet regulation of the same name. However, due to the changes in the competent departments, the political movement, and the natural disaster during 1958 to 1960, the implementation of this reward policy came to a halt. Therefore, in 1962, the Bureau of Invention was established by the State Scientific and Technological Commission with "Regulations on the awards for technology improvement" developed based on the reward policy of 1954. Refer to the specific provisions in Table 2.6 below:

Table 2.5 Regulations on the awards for technology improvement

Amount saved in the 12 months of operation*	Inventions		Technical improvements		Management improvements	
	Annual bonus rate**	Additional reward***	Annual bonus rate	Additional reward	Annual bonus rate	Additional reward
Under 100	30	0	20	0	10	0
100-200	15	150	10	100	5	50
200-500	12	210	7	160	3.5	80
500-1000	10	410	4	310	2	160
1000-5000	6	710	2.5	460	1.25	230
5000-10000	5	1210	2	710	1	360
10000-50000	4	2210	1.5	1210	9.75	600
50000-100,000	3	7210	1	3710	0.5	1860
100,000and more	2	17210	0.5	8710	9.25	4360

* Million Yuan

**Percent

*** Thousand Yuan

Source: The important selected literatures since the state establishment Volume V.

2.1.2.5 Social standing of engineers

The social status of engineers in the PRC is unlike that of other countries. Since communist China was founded, almost all higher intellectuals were mobilized to participate in socialist campaigns, such as land reform, the movement for the suppression of counter-revolutionaries, the Resist-America and Aid-Korea campaigns, and the "three-anti'sand" the "five antis". Except in the period following the anti-rightist campaign, most of them were kept in high positions and, at the same time, enjoyed high political rank and social prestige. The most important qualification for advancement of engineers in the PRC is membership of the Chinese Communist Party. Since the Party is the sole source of power, membership is the means to security and opportunity.[80] For example, of the 1960 graduates of Tsinghua University, 89% were reported to have become members of the

[80] Cheng, Chuyuan: Scientific and Engineering Manpower in Communist China, 1949-1963, Washington D.C. 1965:111.

CCP or the Young Communist League.[81]

2.1.3 Sino-Soviet cooperation and 156 Projects

Without assistance and cooperation from the Soviet Union, it would have been impossible for China to establish and develop its scientific and technological system and technological strength. During the ten years from 1950 to 1959, the Soviet Union assisted China in training scientific and technical manpower in a short space of time, including scientists, engineers, and technicians. Therefore, when mentioning Chinese engineers, we have to emphasize the 156 Aid Program. By reviewing the "156 projects", we can have a better understanding of 1950s Sino-Soviet relations.

2.1.3.1 The origin of 156 Projects

The "156 projects" were fixed after many discussions between China and the Soviet Union. The first projects were determined when Mao Zedong lead a delegation to visit the Soviet Union for the first time. Both of the parties signed a series of treaties and agreements, including the "Agreement on the Soviet Union lending loans to the People's Republic of China", which stipulated that the Soviet Union agreed to provide a loan of 0.3 billion USD to China with a favourable annual interest rate of 1%. It was through this loan that the Soviet Union provided the first 50 large-scale engineering projects covered in the "156 projects", including the energy projects of coal and electric power etc, the basic industrial steel projects, non-ferrous metals and chemical engineering etc. as well as the industrial national defence projects. The second projects were determined when Zhou Enlai lead a delegation to the Soviet Union in August of 1952, with a general principle of aid projects defined by both parties. After that, Zhou Enlai and Chen Yun returned to China, leaving Li Fuchun to continue to stay in the Soviet Union and discuss with the Soviets the details of their aid to the construction projects. It took them eight months to produce a detailed and thorough research on each project; both parties then signed the

[81] Zhongguo Xinwen,China News Service(Canton),Aug.14,1959:11.

"Agreement on the aid from the Soviet government to the Chinese government for the development of Chinese national economy" with the Soviet Union promising to assist China in constructing or reconstruct 91 large-scale engineering projects during 1953-1959.[82] The agreement also provided that together with the 50 projects signed in 1950, all of the 141 enterprises would be constructed respectively during 1953-1959. According to the estimation of that time, these 141 projects would contribute to an increase in Chinese industrial production capacity after their construction and by 1959 critical heavy industrial products in China, such as steel, coal, electric power and oil etc might meet the level of the Soviet Union when it began its first Five-Year Plan, and get near to or exceed the China's 1937 level, when Japan started its invasion.

The third projects were determined in October 1954 when Khrushchev led a delegation to attend the fifth anniversary celebration of the founding of the People's Republic of China. Both of the parties held talks regarding Lushun Port, scientific and technical cooperation between China and Soviet and assistance from the Soviet government in constructing and expanding Chinese enterprises with 10 documents signed, including the "Aids from the Soviet government to construct 15 industrial enterprises for the government of People's Republic of China" and the "Protocol on extending the supply scope of 141 business equipments in the original agreement".

Therefore, the Soviet Union provided 156 projects to aid China, which were generally called the "156 projects". [83] In March of 1955, both parties signed another agreement for 16 new construction projects involving military engineering, shipbuilding and material industry, etc. Then, in 1955, both parties added another two projects through oral agreement to take the total projects up to 174. However, with repeated examinations and adjustments, only 154 projects were finally confirmed. People still called them "156

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[82] 麦克法夸尔，费正清主编：剑桥中华人民共和国史 1949-1966。 北京：中国社会科学出版，1990。MacFarquhar, Roderick & Fei,Zhengqing eds.: The Cambridge History of China Vol.14：The People's Republic, part2. Revolutions within the Chinese Revolution,1949-1966. Beijing: China Social Science Press.1990:184.

[83] 宿世芳: 关于50年代我国从苏联进口技术和成套设备的回顾。当代中国史研究1998(5)：48-49. Su Shifang: Review on imported technology and equipment from the Soviet Union in the 1950s. Contemporary China History Studies 1998 (5): 48-49.

projects," since that number had been published in the plan. As known to all, these "156 projects" aided by the Soviet Union were the core for the construction of the Chinese first Five-Year Plan.

However, with the implementation of the "first five-year" plan and after repeated demonstrations regarding the "156 projects", only 150 construction projects were actually put into development. The actual construction of said 150 projects and their supporting projects changed to a great extent China's heavy reliance on coastal industries and established a partially complete framework for the primary and national defence industries, laying a preliminary foundation for Chinese socialist industrialization.

2.1.3.2 The association of Soviet engineers

In order to practically implement the "156 projects", numerous Soviet experts, including scientists, engineers and technicians came to China to satisfy the urgent needs of construction. In February 1950, when Mao Zedong and Zhou Enlai visited the Soviet Union, they hired for the first time a Soviet design team consisting of 16 members, while a second group of experts constituted of three Soviet design teams was also hired, with a third group of experts constituting 23 Soviet design teams employed in 1951. Based on the "Chinese Archives and Documentary Sources" written by the domestic scholar, Shen Zhihua (沈志华), we find that there were at least 18,000 Soviet experts working in China from 1949 to 1960, with industrial technicians accounting for more than 70%.[84]

Table 2.6 Statistical table on Soviet-aid experts in China from 1950 to 1960[85]

Period	1950-1953	1954-1958	1959-1960	Total
Persons	5000	11000	2000	18000

The amount of Soviet experts working in China was a call for the Chinese government to consolidate its power and develop the economy in three main ways that

[84] Shen, Zhihua: Historical Investigation of Soviet Experts in China. Contemporary China History Studies Vol. 9 No.1 , Jan ,2002:24-37.

[85] So far, More detailed documents recorded the exact number of Soviet experts in China haven't be found, the data is based Shen Zhihua: Soviet experts in China, World Knowledge Publishing House, 2003:410.

Soviet experts provided technical assistance with: I. Through the industrial aid projects including resource development technology, manufacturing technology, design technology and technical standards in addition to machines and equipments with large output and raw materials etc. II. Through scientific and technological cooperation, helping China to work out science and technology planning and carry out theoretical and experimental research on engineering science, as well as with the combination of industrial projects, studying and developing products and providing technical data. III. They helped China to adjust and construct colleges and universities as well as secondary technical schools to take in the numerous Chinese students studying abroad and internal students. The Soviet Union's technical assistance included the provision of technical knowledge and experience, aid in the design and construction of industrial and mining enterprises and infrastructure, the supply of technical data and the training of technical personnel and management. The cost of printed materials consumed by the Soviet Union, the copying expenses for technical documents, the travelling expenses, and the salaries and houses for the Soviet experts were all paid for by China.

Since the first Five-Year Plan was developed to lay a foundation for the industrialization of China, the foreign experts working in China mainly concentrated on sectors of primary industry. Actually, by the end of 1954 82.4% of the experts from the Soviet Union and various countries in Eastern Europe working in the different factories and mining enterprises in China were gathered in the sectors of heavy industry, the first machinery industry department, the second machinery industry department and the fuel industry department.[86] Based on statistics from the Soviet Union, from 1954 to 1957 and during the construction of industrial projects, besides the supply of numerous machines and equipment, design drawings, technical data and various product production permits, the Soviet Union also sent almost 5,000 experts to China (983 specialists in 1954, 963 experts in 1955, 1936 specialists in 1956 and 952 experts in 1957) according to the

[86] Academy of Social Sciences, the Central Archives 1953-1957 People's Republic of China Economic archive Selected: Fixed asset investment and construction Industry volumes. Beijing Chinese Prices, publishing house 1998:386-388.

economic and technical cooperation agreement. By the end of 1956, the number of Soviet experts working in China reached a peak of 3,113, including 2,213 technicians, 123 economic advisers, 403 counselors and specialists in scientific and cultural fields and 374 military advisors and specialists.[87]

In terms of the training of engineers, the Soviet experts had participated in the education reform in the early of 1950s to make the discipline system and regional distribution of higher education for the purpose of training numerous professional talents for large-scale industrialized construction and scientific and technological development. They would also spread knowledge and experience to the Chinese cadres and workers in the factories and enterprises through various methods, such as teaching technical courses, site instructions, translating and explaining documents and literatures etc. Take the First Automobile Works, for instance. During the three-year plant construction from 1953 to 1956, 186 Soviet experts organized more than 1,500 technical courses to instruct 20,000 employees with 470 managerial staff and technicians having been taught and trained directly.[88]

In October 1956, the cooperative relationship between China and the Soviet Union entered into another stage. When the conflict between the Soviet Union and Poland arose, the Soviet Union was forced to promise the withdrawal of military experts from Poland.[89] On October 30, it made an announcement on the development and further reinforcement of the basis for friendship and cooperation between the Soviet Union and other socialist countries and expressed that the Soviet Union would consider calling back Soviet experts working in other countries.[90] This affair affected the Soviet experts in China as well. On August 23 1958, the State Council announced that if any department wanted to employ

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[87] The Shepilov's report to CPSU central,1957.Jan 4. SD10181。Sheng, Zhihua, An Historical Investigation of Soviet Experts in China: Circumstances and Policy Changes. on temporary China History Studies Jan., 2002,vol. 9 no.1:24-37.

[88] Shen,Zhihua: Historical Investigation of Soviet experts in China. Contemporary China History Studies Jan., 2002 vol. 9 no.1:24-37.

[89] Mark Kramer, Hungary and Poland, 1956: khrushchevps CPSU CC Presidium Meeting on East European Crises,24 October 1956, Cold War International History Project Bulletin, 1995, No. 5: 50; Renmin Daily 1956.Nov.1

[90] Renmin Daily 1956.Nov.1.

Soviet experts, they must strictly follow the "fewer but better" principle. They would not be allowed to employ any Soviet expert unless new technology or new disciplines were required, or there was weakness in the work. Meanwhile, if employing short-term experts could solve the problem, employing long-term experts was not allowed. If it was applicable for several organizations to employ an expert, then a joint employment was required.

Therefore, due to the implementation of this new policy, the number of experts sent by the Soviet Union to China was gradually reduced. However, not all departments reduced their demand for Soviet experts. Some of them even required more or only just began to employ Soviet experts; this mainly happened in the field of new technologies for national defense. By the end of March 1957, the Soviet and Chinese governments entered into an agreement regarding assistance for the People's Republic of China in terms of particular technology with provisions including that the Soviet Union would dispatch five experts to China for the purpose of organizing the relevant professional teaching and technical courses for jet technology. Moreover, several months later, the Soviet Union decided to set up three additional majors including solid rocket, remote control (gyroscope) and remote control (wireless) with 2-3 experts additionally employed for the control specialty.[91]

However, at the same time the Great Leap Forward, starting in 1957, severely interfered with the work of Soviet experts. Although they did not agree with industrial construction through a great leap forward, their opinion and experience did not count for as much as before the movement. Meanwhile, although some organizations would allow the Soviet experts to play their role and respected their studies, there were still lots of enterprises or other organizations failing to treat the Soviet experts' technical requirements and the opinions correctly. Some of the enterprises even refused to strictly follow the technical standards, design requirements or innovation on the processing rules. In fact, Moscow constantly received relevant reports regarding such situations. For example, the Soviet government was informed that in the second half of 1958, CCP industrial enterprises had cancelled all of the technical departments that were established based on

[91] Zhou,Junlun: Nie,Rongzhen Years Book. Vol 1.People's Publishing House.1999: 605-624.

Soviet technical solutions and regulations, abolishing all of the necessary technical specifications and standards. Therefore, it seemed that although Soviet experts still stayed in their positions, enjoyed their salaries and assumed the production responsibilities stipulated in the contracts, they were unable to practically perform their duties. For example, in April 1959, the 12 Soviet engineers working in Wuhan Metallurgical Co. complained that they had not been allowed to work for more than three months. As a matter of fact, all Soviet regulations, standards and technical rules were abolished in the enterprises.

2.1.3.3 The cooperation between Soviet engineers and Chinese engineers

During the collaboration between Soviet and Chinese engineers, the key decisions were always made by the Soviets while advice from Chinese engineers was sometimes neglected; see, for instance, the Sanmenxia Dam water control project.

The Sanmenxia water-control project was the first large-scale one of its kind built in the Yellow River. The nation invested a huge amount of manpower, and material, and financial resources in the project and had high expectations that the river would be clear for the first time in several thousand years. However, the project caused serious problems soon after it was finished due to its design defects - it had to be rebuilt, which indicated severe mistakes in the original decision-making.

The Sanmenxia water-control project was decided upon by the CCP , and was also one of the 156 Projects.[92] With the assistance of Soviet experts, the government finished the report on the technological economy of Yellow River management planning in 1954. In 1955, the NPC and constructional engineering institution of the Sanmenxia reservoir and hydropower station passed on the report.[93] In April 1956, Soviet experts further improved the design of the engineering project. In 1957, the Ministry of Water Resources

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[92] Including experts deputy chief engineer and hydraulic, hydrologic and hydraulic calculation, hydraulic construction, engineering geology, irrigation, navigation and other six aspects.

[93] 顾永杰：三门峡工程的决策失误及苏联专家的影响。自然辩证法研究。第 27 卷，第三期。2011 年 5 月。第 122-126 页。Yongjie Gu: The Sanmenxia Project Decision Making Errors and the Impact of the Soviet Union Experts. Studies in Dialectics of Nature.Vol.27,No.5.May,2011:122-126.

called in 70 scholars and engineers to discuss the project and to give suggestions on the schema of Russian experts. It is noteworthy that the Sanmenxia project was started two months earlier. The discussion was designed to show the democracy of the nation rather than to garner substantive technological breakthroughs or propose instructive suggestions.

However, in the debate, Huang Wanli (黄万里), an expert in hydraulic engineering, lodged an objection and stated his theoretical basis in detail, but most people disagreed his opinion. Except for Wen Shanzhang (温善章), who proposed schemes on the rebuilding of little dam reservoirs and flood detention, most people kept silent, and others argued that the water in the Yellow River would be clear after the Sanmenxia dam was constructed.[94] Afterwards, Huang Wanli indicated that quite a few did not support the ideas of the Soviet experts, but dared not to hold oppositional opinions. Someone told Huang in private that they agreed with him, but dared not to say so since Soviet experts formulated the idea. Huang believed that those experts who agreed with the construction of Sanmenxia dam did know the truth, in fact; however, since Soviet experts, as well as the party leaders, said that the dam should be constructed, they just followed suit.[95] This made Huang angry, and he published an article that insinuated that some engineers had lost their scientific conscience; this left him regarded as a rightist who went against the party and socialism in the anti-rightists struggle. In 1961, Huang was ordered to work in Miyun where he collaborated with rural laborers of Chuangli. Even worse, he was sent to Sanmenxia to dig toilets as a punishment during the Cultural Revolution.[96]

However, the problems of the Sanmenxia project exposed themselves very soon. In 1960, the Sanmenxia dam started to store water, but only a half year later there were severe problems, including sediment deposition, farmland being submerged on both sides of the

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[94] 顾永杰：三门峡工程的决策失误及苏联专家的影响。自然辩证法研究。第 27 卷，第三期。2011 年 5 月。第 122-126 页。Yongjie Gu: The Sanmenxia Project Decision Making Errors and the Impact of the Soviet Union Experts. Studies in Dialectics of Nature.Vol.27,No.5.May,2011:122-126.

[95] 顾永杰：三门峡工程的决策失误及苏联专家的影响。自然辩证法研究。第 27 卷，第三期。2011 年 5 月。第 122-126 页。Yongjie Gu: The Sanmenxia Project Decision Making Errors and the Impact of the Soviet Union Experts. Studies in Dialectics of Nature.Vol.27,No.5.May,2011:122-126.

[96] 许水涛：黄万里与三门峡工程，下。人物春秋。2007 年第三期。Shuitao Xu：Huang and Sanmenxia Project, II.People.No.3,2007:14.

lower Weihe River (渭河), enlargement of land salinization, the collapse of reservoir banks, while secondary problems kept on coming. It was said people spent three years to create an issue and 43 years to solve it. The project was rare in engineering history, but it was not a simple technological mistake. Instead, it was the result of the unbalanced relationship between Soviet and Chinese engineers during the decision-making process.

The idea that the "today of the Soviet Union is the future of China" once gave countless Chinese people a bright vision of future, and the national policy of "leaning to one side" made China blindly worship the Soviet Union and Soviet experts in the Cold War. In 1954, when Soviet experts helped China manage the Yellow River construction planning, they held that conserving water and soil and blocking mud could make the river clear. Russia did not have rivers with as much silt as the Yellow River in China. The Yellow River was in China, and no people had a better understanding of the merits and demerits of the Yellow River and difficulties as well as the success and failure of water control there than the Chinese people. However, one sentence from Soviet experts made people take action to clear the river. Thus decisions that historically were never taken, were immediately decided. For example, the Japanese and the KMT had discussed the Sanmenxia dam project, and it was studied after the liberation, but the decision to dam the river was not made.[97] When Soviet experts said it was possible, the decision was made quickly.

Based on this case, the relationship between Soviet and Chinese engineers was unbalanced. The Soviet engineers' received more attention and respect during the period of the 156 Projects; on the contrary, the opinions of Chinese engineers were neglected and suppressed when there were different voices on the two sides.

2.1.3.4.The impact of 156 Projects

1960 is the critical year when Sino-Soviet relations deteriorated and the Soviet Union put a sudden stop to the technical assistance it provided to China. On July 16 1960, the plenary session of the central committee of Soviet Communist Party discussed

[97] 许水涛：黄万里与三门峡工程，上。人物春秋。2007 年第三期。Shuitao Xu：Huang and Sanmenxia Project, I.People.No.3,2007:14.

Sino-Soviet relations and announced the news of the recall of their experts. After 1960, China continued with its construction of large-scale projects without the assistance of the Soviet Union, and explored a road for the development of industrial modernization suitable for their own national conditions.

The Sino-Soviet alliance lasted only a dozen years, with their honeymoon period continuing only several years. However, the impact of the Soviet Union on China was very profound. Starting from the 1950s, the Soviet Union sent thousands of engineers specialized in industrial technology and military training and state administrative management consultantcy to work in China. This was the most direct way of introducing the Soviet technical system consisting of Soviet technology and models to China, rapidly improving Chinese technology, science and educational levels and training a technical cadre who not only mastered professional knowledge but also stayed faithful to the people's government of China. All of this played a significant and positive role in large-scale industrial and national defense construction. When talking about the introduction of Soviet technology, Qian Sanqiang emotionally said that: "In terms of science and technology at that time, their assistance to us is selfless indeed. Moreover, things are totally different regarding today's exchange with USA and Japan, etc."[98] During the period from the mid 1960s to the end of the 1970s, Soviet technology constituted the foundation for China's development of technology, industry, national defense and science; or, rather, Soviet technology had become the primary objective to be followed. However, at the same time the weakness of the Soviet-type technical system and industrial system began to emerge. Since the early 1980s, the Soviet technology introduced on the one hand continued to act as the cornerstone for technical progress, but on the other hand had been replaced by newly introduced Western and Japanese technology, leaving the Soviet-type technical systems and the relevant industrial objects in need of reform.

[98] 钱三强主任的讲话， 1990 年 12 月 17 日。 院史资料与研究， 1991 。Director Qian Sanqiang's speech, December 17, 1990 History of hospital data and research, 1991, (1): 11-20.

2.2 Cultural Revolution period, 1966-1976

Many call the period of 1966-76 the time of Cultural Revolution. The Cultural Revolution was a very intensive and extensive social revolution aiming at changing people's social consciousness, the parallel of which would be hard to find in world history. This period was distinguished from both that of 1949-1965 and that after 1977 by the hallmark of Maoist radicalism. From the mid-1960s to mid-1970s, as the relationship between the CCP and Communist Party of the Soviet Union ruptured due to their ideological differences, the original socialist bloc no longer existed. Sino-Soviet relations were in an unusual state of tension. In such a complicated international context, the CCP answered the essential problems of socialism based on its understanding of class struggle, politics, and other factors. On the one hand, the CCP criticized the CPSU's reform of the Soviet model; on the other hand, it laid undue emphasis on class struggle and the dictatorship of the proletariat, and pushed the model to the extreme. It was believed that the impetus of for launching the Cultural Revolution was the need to prevent capitalist restoration, maintain the purity of the CCP, and seek China's road to socialism. However, in this process, Mao Zedong estimated the political situation of the party and country, which had developed to a very bad level. Mao held that revisionism existed in the Party, and the Party and country were facing the real danger of the restoration of capitalism; furthermore, measures taken years ago, such as the transformation of intellectuals, the "Four Clean-ups" (四清) Movement in rural area, the "Five Antis" (五反) Movement in cities, and ideological criticisms, could not solve the problems. Therefore, only by firmly taking steps to openly and comprehensively mobilize and rely on the masses from the bottom up could the dark side of the Party and country be revealed, and the power usurped by the so-called "capitalist road" be seized back.

The reason why this paper has listed events that happened in these 10 years as a separate section is because at this stage the development of Chinese engineers encountered unprecedented setbacks with the slogans of "against technical authority", "against revisionism". The field of technology and education was accepted as the hardest-hit area in the Cultural Revolution. During this period, scientific and technical workers were persecuted. In the factory, many technical departments were dissolved, and technical data was burned; moreover, technicians were sent to workshops or driven to the countryside to work. Large numbers of engineers were labeled as "Capitalist roaders", "reactionary authorities" and "stinking number nine";[99] universities stopped enrollment for three years the educational revolution made a serious dent in the development of talent.

However, from the history of science and technology achievements in the PRC, it is not hard to find that China's technological development was not stagnant, and made significant achievements in some areas, such the successful development of China's first atomic bomb in 1964. On June 17 1967, China's all-equivalent hydrogen bomb test succeeded. On April 24 1970, 'Long March 1', a self-developed rocket carrying the 'East is Red 1' man-made Earth satellite was successfully launched; November 29 1975, the manmade earth satellite was successfully recovered for the first time. In the meantime, on December 29 1968, our own designed and constructed Nanjing Yangtze River Bridge opened to public transportation; in 1970 the Gezhouba Water Control Project began construction. How do we explain this contradiction? There is a need to do more study on the Cultural Revolution to go a little deeper than its surface structure.

2.2.1 Policy and Planning

Although the Cultural Revolution was not directly about science and technology, many of the key issues involved had significant relationships to and implications for science and technology. The attitude of the CCP to science and technology affected the social status of engineers. So, it is necessary to analyze the trend of economic and scientific policy first.

[99] A phrase coined in the culture revolution to discriminate intellectuals

2.2.1.1 Economic development plan

With the standpoints agreed by current Chinese domestic scholars, the primary national development plans formulated in 1950s were adopted in the late 1960s and early 1970s. Because of the weakness of the government, and especially the plan makers, during the Cultural Revolution, it was impossible to seriously consider changes that could be made in development. Most new ideas were attacked, so the safest way was to follow suit. From the formation of the third Five-Year Plan and the fourth Five-Year Plan it was not difficult to judge that, compared to the national economic development plan before 1965, the development and implementation of the third and fourth Five-Year Plans seemed blind and unrealistic. The third Five-Year Plan (1966-1970) focused on preparing the war. At the central working conference in September 1965 "the Outline of the Arrangement for Third Five-Year Plan (draft)" was discussed, and guidelines and tasks of the third Five-Year Plan were proposed, to be based on the war, give priority to national defense, and prepare for a large battle. Since the Cultural Revolution broke out, the third Five-Year Plan remained in the outline put forward in September 1965 so that the emphasis of the Plan was shifted to "prepare for the war." During the period of the third Five-Year Plan, the Cultural Revolution posed considerable damage to the national economy, and there was successive retrogression in the completion of the plan. It was high input in 1970 that helped to complete the third Five-Year Plan. The fourth Five-Year Plan was formed during the Cultural Revolution; there was no formal plan, only the "1970 Plan and the Outline of the Fourth Five-year National Economic Plan (draft)". In the time of the fourth Five-Year Plan, military-centered heavy industry became a priority. Compared to the Great Leap Forward, its size and growth rate went unabated. Infrastructure was extended again and widely distributed. China's limited economic and technical resources were almost used in the construction and expansion and to increase production. China's technology remained stagnant in the scattered allocation of economic and technical resources, and technology was introduced mostly by copying; meanwhile, in the Cultural Revolution, science, technology and education, which closely related to technological innovation, were badly hit. Talent development, business management, and the standardization necessary for technical progress were in chaos. So, apart from several advanced technologies, there was little technological innovation based on the technology introduced.

2.2.1.2 Scientific and technological policy

Although the Cultural Revolution was not directed against science and technology, many of the key issues involved had a direct impact on science and technology. The cultural transformation of national defense, education policy, agricultural policy and people were all closely linked with S&T policy. On the future of Chinese society, various viewpoints struggled against each other, which also included the relationship between S&T and the redistribution of power. The flames of the Cultural Revolution were then directed towards the S&T world, leading to severe damage to the S&T system for three years. In order to achieve their political aims, 'Revolutionaries', the basis of Mao's misjudgment regarding technology, vigorously attacked "fourteen suggestions for research work" as "typical revisionist documents" and "Evil Principles for Restoration of Capitalism". They took advantage of the power in their hands to dismantle the scientific management departments, disintegrate scientific research institutions, deny basic theoretical research, disband researchers, dissolve higher education institutions and destroy equipment and intelligence information. In 1970, when the National Scientific and Technical Commission and Science and Technology Cadre Bureau of the State Council merged into the Chinese Academy of Sciences, a large number of research institutions affiliated with Chinese Academy of Sciences were dissolved. By 1973, there were only 1.3 million researchers in the Chinese Academy of Sciences, and only 53 research institutions remained, which reduced to 36 in 1975, while nearly all fundamental research stopped. More than 300 scientific journals ceased publication nationwide and more than 30 million learned scientific and technical workers were sent to "May Seventh Cadre Schools", engaging in backbreaking labor in the mountains, pastures, and rural areas. In the meantime, many intellectuals were labeled as "spies of the Kuomintang", "spies of the Soviets", and "active counterrevolutionaries" and even thrown into "cowsheds", actually a variation of jail, suffering insults. A "Dictatorship of the masses" was allowed.[100]

The scientific and technological situation had eased in early 1970s. On August 10 1972, according to Zhou Enlai's proposal, a national S&T working conference was held in Beijing. The conference was a measure by Zhou Enlai to correct the "left" in S&T, and it was also the only national S&T working conference held during the ten years of turmoil. There were 249 representatives from different provinces, municipalities, autonomous regions, and ministries and commissions of the State Council attending the conference. In the meeting, attention was paid to issues of strengthening research and fundamental theoretical construction, and a consensus was reached. In January 1973, the "National Science and Technology Conference Minutes (Draft)" was issued by the State Council. However, the atmosphere was dominated by the "left" trend, the role and outcome of the conference was limited, and the conference could not represent the S&T policy in the Cultural Revolution. The scientific and technical workers did not regain confidence and hope until 1975 when Hu Yaobang (胡耀邦) reorganized the Academy under the direction of Deng Xiaoping (邓小平).

2.2.2 Changes in engineering training program

The engineering educational system also underwent substantial alteration. During the Cultural Revolution, the disastrous engineering education revolution caused a temporary shortage of engineers in the following 20 years. Political struggle and the "education revolution" meant an entire generation lost the opportunity of systematic and comprehensive school education. The damage to engineers' development was immeasurable. Developing "red engineers", the goal of higher engineering education, was replaced by the slogan of developing "ordinary workers". Engineers were criticized as a "bourgeois technical authority". Due to the ten-year chaos, China cultivated at least one million fewer students. S&T teams did not have enough reserve force in the period.

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100 Science and Technology in Modern China. Modern China Book Roon.1991.Dec.First Edition:43.

2.2.2.1 Education revolution in engineering universities

During the Cultural Revolution, higher educational institutions began to stop following the admission scheme from 1966. On June 30 1966, the Higher Education Department issued a notice to institutions to stop selecting and sending students abroad. Then, in July, the Higher Education Department informed embassies abroad to defer receiving foreign students. From then on, China did not sent students abroad for seven years, and did not accept foreign students. At the end of 1967, some regions and schools that had earlier achieved coalition and established revolutionary committees devised an education reform program, and then began the so-called "Education Revolution". The Education Revolution involved almost all aspects of the enrollment system, teaching content, and teaching methods.

First of all, as for recruitment, after the peak of the political chaos, in the early 1970s, a number of higher education institutions reopened to provide training to 'worker-peasant-soldier-students' without formal academic requirements for admission. These students were selected from the workplace on the basis of their revolutionary spirit rather than their academic qualifications. From July 1970 to the end of the year, some universities tried to recruit students for the first time after the Cultural Revolution - 41,870 students were recruited and entered universities in early 1971. They were named the 'worker-peasant-soldier-students' of 1970. Afterwards, the grades of students were named after the year of recruitment and the students entered university the following year. In 1972 more universities restored enrollment, and the number of students admitted surged up to 133,553. Then in 1973, 150,000 students were enrolled, and a literacy test was proposed to ensure that students had a secondary or higher educational background. In 1974 165,000 students were recruited. The recruitment of 1973 was blamed for "following the methods of old college entrance examination", and it was proposed that literacy could only be tested by interviewing and discussing, and a small number of children from exploited classes and "educatable children" could also be recruited reasonably. 1976 was the last year when the universities recruited 'worker-peasant-soldier-students' with the largest enrolling 217,000, which was about the same with planned enrollment in the first year that college entrance examination resumed (after increasing enrollment in the spring of 1978, the actual number of students in 1977 reached 273,000). So far, a total number of 940,000 'worker-peasant-soldier-students' had been recruited over seven years, accounting for 21.4% of the number of college graduates since the PRC was founded. These numbers of students were unprecedented in the history of education. Under the examination-oriented and score-based mechanisms, students from scholarly families had more advantages than those from working families. The abolition of college entrance examinations meant that hundreds of thousands of children from illiterate and poor families were free from "cultural oppression", obtaining access to higher education.

Just as the song "Jingpho[101] girl goes to university" goes,

Mouth harps play, and the birds sing/ folk songs invite colorful clouds to crowd in the sky

Mu Ding will go to the university in Beijing/ every cottage is in elation.

Old secretary sees her off / towards the sun; they go through the forest/ Old secretary is talking to Mu Ding all the way/ every word counts

"Mu Ding, the way to Beijing is of great distance, don't get lost!

Mu Ding smiles and says the word by word,"

No matter how dangerous the road ahead is, I have the star in my heart. [102]

However, due to the weak educational background of 'worker-peasant-soldier students' and the cancelation of the college entrance examination, many graduates could not obtain qualifications from higher engineering institution. In May 1972, according to surveys made by universities in Beijing, the educational background of students was thus: 20% of students had attended high school, 60% had attended middle school, and 20% only had studied primary school courses. It can be seen that most had studied in middle school for three years, and then three years at university, so the total length of school years only reached the level of secondary technical school before the Cultural Revolution.

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[101] Jingpho People or Kachin people is one of the 56 ethnic groups officially recognized by the PRC. Chinese territory of about 100,000 people, mainly in the junction between China and Burma, this song reflected that the workers-peasant students can get equal education change during the education revolution period, even the poor peasant children can go to university.

[102] Renmin Daily 1973.Jan.1.

Many universities had to spend six months helping them with middle and high school courses, so there was not much time left for learning university courses. Thus, except a small number of 'worker-peasant-soldier-students', most of them did not reach college level. On April 12 1980, at the graduation ceremony of the last of the 'worker-peasant-soldier-students', Jiang Nanxiang (蒋南翔), the veteran minister of education, concluded that there were top engineers among 'worker-peasant-soldier students'. However, he argued that they should realize their weaknesses, and learn more about professional courses. Then, with reference to the junior college level of national educational system, they were conferred a three-year college degree. Certainly a few of them were quite outstanding. According to the survey conducted by the State S&T Commission, 'worker-peasant-soldier-students' with a high level of professional knowledge and capacity for work accounted for 10%-15%. As the data showed, since the national postgraduate entrance examination resumed in 1978, 75% of the graduates in the first three years were 'worker-peasant-soldier-students'. As an individual behavior, learning in private had never stopped. Most students from 1977 to 1988 had the experience of learning by themselves privately.

As for reform of the school system, the program of Tongji University could serve as an example. In 1971, the university undertook a reform program to establish a triad of May Seventh communes. The overall idea was to transform the university into a trinity institution, combining production, education, and design (including research), called a "May Seventh commune". The institution functioned as production design unit as well as an educational unit. The program could be illustrated as a building materials company + several majors in building materials + a design institute = a commune.[103] The Construction department and Architecture department, the backbones of Shanghai Tongji University, mainly cultivated technicians and engineers in the field of industrial and civil construction, architecture, city planning, construction organization and management. With the establishment of the "May Seventh commune", the original departments and teaching and

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[103] Tongji May 7th communes scenario on the establishment of the "Trinity"(Draft); Education criticism,1967.Vol 13: 4-5.

research sections were canceled, and more than 70% of the cadres were replaced. Many teachers and professors were incorporated into construction teams and labored with students; such groups were called “architectural field armies”. Among 259 teachers of two departments, 92 of them suffered persecution. The teaching approach of the commune was called the “only effective way which combined with typical engineering” for engineering schools. Reducing the teaching hours for basic theory, breaking the system and sequence of basic theory to coordinate with engineering education, and learning for use meant students lacked basic knowledge and could hardly meet the needs of professional work. Among the first 181 graduates of a “May Seventh commune”, by the end of 1977, only 67 students had the competence to engage in researching and teaching, accounting for 37%. The rest were converted to administrative work. The school program of Tongji University highlighted a triad of “production, education, and scientific research”, and “students, teachers, and workers”, which was typical during the Cultural Revolution. After the Universities began to recruit ‘worker-peasant-soldier-students’ in 1970, the idea of “go to the university, run the university, transform the university” was put forward and it developed several times to a summary that “open the university to society, cooperate with factories, run factories in the university, factories bring along the university, create a new system combining teaching, research, and production” ,“run the university facing the society” in 1971.[104]

As for the discipline design, the proportions of different disciplines were very unreasonable. Many liberal arts universities were dissolved. In 1971, six law universities were revoked and faculties of law in comprehensive universities stopped or reduced enrollment. Of 18 financial institutions, only two remained. In the meantime, many science majors were merged or “developed closer to engineering”. Moreover, compared to liberal arts and science universities, most engineering universities survived, but engineering majors were subdivided into smaller ones to conduct “teaching combined with a typical product”. Textbooks used in engineering universities broke away from theory and

[104] Tongji May 7th communes scenario on the establishment of the “Trinity”(Draft); Education criticism,1967.Vol 13 :4-5.

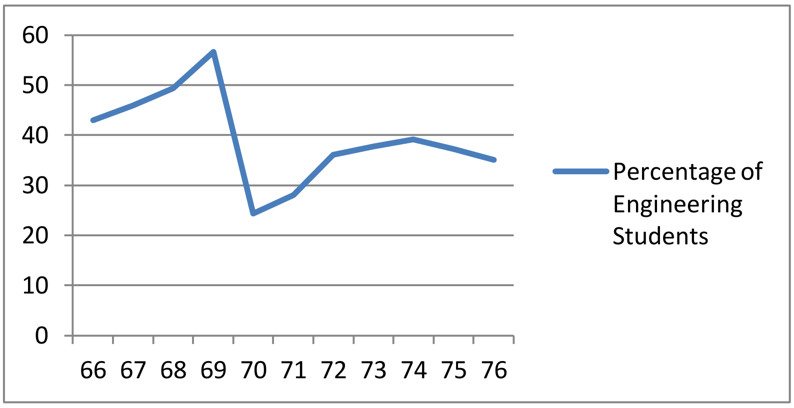
highlighted practice. In "May Seventh communes", the system of teaching materials for past building construction majors was analyzed and it was concluded that the system was out of place in proletarian politics and production practices and was against the law of cognition; it consisted of too many courses and subdivisions. Then from September 1969, the original "Descriptive Geometry and Engineering Drawing", "Surveying", "construction materials", "construction structure", and "construction" were combined into one course, "background knowledge of building construction". 1,000 hours of classroom teaching was reduced to 250 hours with another 250 hours for production practices. Next, traditional teaching and research sections that were based on the characteristics of each discipline were all abolished to build another one organized by "the principle of comprehensiveness and large circulation" (commonly known as "responsible group"). "Responsible group" gathered teachers of basic and professional courses together to form a team responsible for teaching the students from beginning to the end.

Thus the tasks of teaching often changed and their direction could not be certain. Many basic course teachers had to teach courses beyond their ability. For instance, physics teachers had to teach mathematics, mechanics teachers had to engage in measurement. The majority of teachers were busy in business such as working on projects, looking for the markets, etc., and some even could not finish projects that had lasted for several years. Teachers could hardly devote themselves to the development of their disciplines, and teaching materials and experience could not be accumulated.

In 1965, there were 434 higher education institutions in the country, by 1971, there were only 328 left. By 1976, the total number of universities was 392. These colleges and universities included 29 comprehensive universities, 126 engineering universities, 38 agriculture universities, 6 forestry universities, 89 medical universities, 58 regular universities, 10 foreign language universities, 7 financial universities, 7 sports universities, 14 art universities, and the other 8. Among the students, 7% studied science, 35.1 % Engineering, Agriculture majors accounted for 8.9%, and Forestry students took up 1.5%, 17.4% of students majored in medicine, 19.4% of students majored in education and teaching, 7.6% studied liberal arts, 1.2% specialized in finance, students of law made up

0.1%, Sport majors accounted for 1%, and Art students for 0.8%.

Figure 2.3 Percentage of engineering students in universities, 1966-1976



Source: Achievement of Education in China (statistic date) 1949-1983, People's Education Press, 1984:68.

Table 2.7 The enrollment of a part of engineering subjects,1970-1976

Year	Applied Geology	Min-ing	Power Enginee-ring	Metall-urgy	Mechanical enginee-ring	electrical machines instrum-ents	Radio electro-nics	Chemical Engin-eering	Civil Engineering Architec-ture	Total
1970	204	999	418	369	2575	432	2143	743	542	10450
1971	300	690	470	501	3100	710	2990	1350	1570	13550
1972	2829	2184	1785	2463	12673	2782	5266	4703	4682	50395
1973	2553	3571	1917	3931	14612	2627	5534	4998	5461	56671
1974	3465	3346	2372	2769	17057	1672	6846	5222	6420	63283
1975	3535	3588	2825	2946	16878	2550	6966	6417	7212	65870
1976	3837	3562	3165	3523	19054	1958	8876	5845	6912	71618

Source: Achievement of Education in China (statistic date) 1949-1983, People's Education Press, 1984:70.

Table 2.8 The Situation of Chinese engineering colleges, 1965-1976

Year	Number of universities		
	Total	Comprehensive	Engineering
1965	434	27	127
1966			
1967			
1968			
1969			
1970			
1971	328	27	115
1972	331	27	116
1973	345	28	118
1974	378	29	120
1975	387	29	123
1976	392	29	126

Source: Achievement of Education in China (statistic date) 1949-1983, People's Education Press, 1984:51.

2.2.2.2 Factory-Based training of technical personnel

The other project of engineering education in factories, namely "mandatory institutional innovation" was the model of the July 21 University. It issued the July 21 instructions added by Mao Zedong in the editor's note: "It is necessary to establish universities, but the universities that I mainly refer to are science and engineering universities. We should shorten the length of schooling, reform education under the leadership of proletariat politics, and change workers into technicians similar to the Shanghai machine tool plant." On July 22 1968, the People's Daily published the survey on the Cultivation of Engineering Technicians from the point of view of the Shanghai Machine Tool Plant.[105]

The July 21 instruction was derived from a false report about the Shanghai machine tool plant in July 1968. The false report fabricated that in the factory 350 employees, who graduated from universities, fell far behind in thought and practical ability compared to 250 workers. It also collected false words or misstatements to deliberately belittle the former, and to exaggerate workers' achievements. For example, it reported that Cao Wanqian

[105] Renmin Ribao (People's Daily). July, 22, 1968.

(曹婉倩), a doctor who had studied in the Soviet Union, had no working achievements, whereas a technical worker, who began as an apprentice, designed a flat grinder that filled up a blank and got up to an international advanced level. In fact, the axletree, which is a part of the flat grinder designed by the technical worker, was the experimental result of Cao. However, the flat grinder was neither at the international advanced level nor could it fill in the blank.[106]

On the basis of the false data, concocted for a political purposes, the report drew the conclusion that the higher education technicians were infected with "education of revisionism", that they ignored ideological transformation, always thought of their own gain, and feared losing face. Meanwhile, they tended to be hedged in by rules and regulations so it was not easy for them to create new technology; on the other hand, because worker technicians were free from the bondage of spiritual shackles, they dared to fight against superstition, inappropriate rules and regulations. Therefore, they leapt forward.

The report, based on a fictional conclusion, then proposed "the direction of education revolution":

1. It is unreasonable for students to be leaders after their graduation. They should join ordinary workers and peasants first. According to the needs of practical production, some can take part in technical work and also need to spend particular time in labor, while others continue to work as workers and peasants.

2. "Schools require the experienced workers to be teachers giving lectures that were given in the workshop."

3 "Select graduates from junior and senior high schools with good political thought and two to five years work experience to enter universities for further study."

4 "A large number of technicians from schools plagued by a revisionist education have many problems in their world view and attitude. However, they should thoroughly criticize the personal fame and gain of bourgeois ideology as well as be organized to be workers by stages."

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106 Guangming Ribao. April 14, 1984.

The July 21 University and May Seventh University were derived from Mao Zedong's educational instructions. The significance of these schools in the Cultural Revolution was so exaggerated to highlight their politics that their functions were weakened. In the national conference on education held in the spring and summer of 1971, some people not only suggested defining these schools' position in the national education system, but also proposed classifying them into the range of factory-run education, social education and mass education, adult education and free education that existed in the Chinese and foreign history of modern education, and not to confuse them with general education. However, this correct view was dismissed as an attack on new movements and it was insisted that the July 21 University was the new school of the Cultural Revolution. It made a mess on purpose to use these schools to challenge informal universities.

Since then, many places subsequently followed the Shanghai machine tool plant to set up "July 21 Universities". They recruited students from local factories, and those students would go back to workshops after graduation. Enrollment conditions stipulated that workers should have more than three years' practical experience and a junior high school diploma, poor middle peasants, be demobilized soldiers and young cadres. Recruitment was by means of mass recommendation; leaders' approval and schools review. Some universities implemented work-study programs. However, some universities were entirely released from full-time work but not from labor, and they required workers to go to the workshop regularly.

However, these kinds of universities were not reliable. In order to cater to the political movement, like the old saying: "While in the movement people go to great lengths, but after it nobody cares about it." Taking Shanghai as an example, in 1968 there was only one July 21 University. In 1969, 12 universities were built, and 36 in 1970. However, since then, the development of universities came to a standstill. In 1974, affected by the movement criticizing Lin Biao and Confucianism, universities increased fivefold, and the number reached 173. In 1975, they began to study the theory of the dictatorship of the proletariat as well; 244 universities were built in March, 302 in April and 368 in May. It should be pointed out that in 1975 and 1976 the supposed of more than 30,000 new July 21

Universities were false statistics. The so-called university in many places was just a resolution, a plan, or just a signboard. The funds, teachers, classrooms and students were still uncertain. Those schools were similar to the "campaign schools" in "Educational Great Leap Forward" of the year 1958.

Table 2.9 Situation of July 21 Workers University and College of communism labor in 1976

Category	"7.21"full-time Colleges	Communist Labor Colleges "5.7" Colleges
Colleges	33374	7449
Graduates	36610	111832
Enrollment	138162	482598
Students	201998	576801

Source: The Yearbook of Education Statistics in 1976 and Chinese Education Status of 50 years produced by the Ministry of Education development and education management information center.[107]

2.2.3 The treatment and daily work of engineers

After the intellectual movement and Three-anti and Five-anti Campaigns, the social condition of engineers and other scientific workers were getting worse, especially during the period of the Cultural Revolution. The Notice on May 16 1966 required whole party members to "uphold the banner of the great proletarian cultural revolution", to thoroughly expose the so-called "academic authority" of the reactionary bourgeois, to criticize reactionary bourgeois ideas in academia, education, the press, publishing and literary circles as well as to seize the leadership in those cultural area".[108] At the same time, the Liberation Daily (解放日报) published an editorial named "Contempt for the Bourgeois Technical Authority" that blamed science and technology experts for "clinging to the foreign frame and looking down on the practical experience of the masses and

[107] Chinese education Year Book (1949-1981), Chinese Encyclopedia Publishing House,1984:593-594.

[108] 1966 年 5 月 16 日，中共中央政治局扩大会议在北京通过了毛泽东主持起草的指导"文化大革命"的纲领性文件《中国共产党中央委员会通知》。The Notice on May 16: The guide "Cultural Revolution" programmatic document" Notice of Communist Party of China Central Committee "(May 16 notice) by Mao presided over the drafting in the enlarged meeting of the Politburo in Beijing.

overthrowing the bourgeois technical authority that hindered the development of science and technology". However, what kind of expert was a "reactionary academic authority"? What was a "reactionary view"? The document did not give a clear definition. It's vague description led to confusion and absurdity in practice. As a consequence, a relatively backwards scientific culture emerged and a few intellectuals suddenly became enemies of the "revolution"; many engineers with outstanding achievements were accused of being "revisionists" and "bourgeoisie reactionary authorities". They were massively criticized and physically humiliated. Under the leftist influence, the document "Sixteen Provisions" also provided the following requirements: Scientists, technicians, and ordinary members of working staff, as long as they were patriotic, worked energetically, were not against the Party and socialism, and maintained no illicit relations with any foreign country, should be looked after. Efforts should be done to help them gradually transform their world outlook and their style of work.[109] However, affected by Party committees and the government at all levels and the arrival of national chaos, these provisions were never implemented.

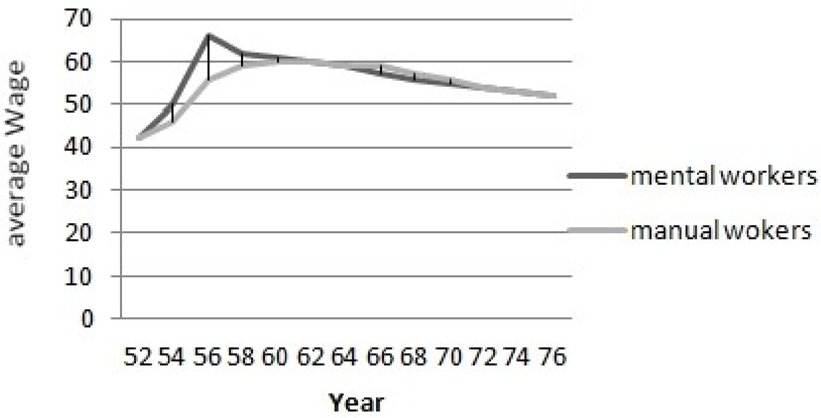
The CCP believed that to succeed civil revolution needed to launch a mass movement, so in science and technology development, the "Mass Line" was also a successful way to achieve the four modernizations. Therefore, efforts to reverse the organizational differentiation between research and prduction and the grouwth of social stratification and social distance between educated scientists and engineers and the masses had been made. A new form called "three in one" (三结合) appeared for breaking down barriers between scientific research and production. On October 5 1967, the People's Daily published an article *New Experience on Office Revolution Offered by May Seventh Cadre School in Liuhe*. It cited Mao Zedong's instruction that required cadres who were not weak and disabled to do manual labor by steps. It was a good opportunity for the cadres to learn again. Since then, a large number of cadres were arranged to go to "May Seventh Cadre schools". In response to the call for studying, some scientific research institutions applied

[109] Point 12 on "Policy towards scientists, technicians and ordinary members of working staffs". Decision of the Central Committee of the Chinese Communist Party Concerning the Great Proletarian Cultural Revolution (adopted on Aug.8 1966),Beijing Review,1966 No.33.

so-called "triangular organization " (三三制). According to this system, a third of people were engaged at the forefront of production and gave suggestions, a third of people stayed in the lab for scientific research and the rest worked in production for a long time to practice daily work. The three groups took turns at working. The first group and the third group gave feedback on the scientific research activities so as to link production with scientific research activities.

As well as in scientific research institutions, the "Mass Line" also ran deep into the factory. From 1969 to 1970, enterprises began to abolish unnecessary management rules and regulations. Professionally trained technicians and engineers had to spend much time in activities that non-professionals could be engaged in. In a meeting, a technician involved in the revolution explained that over recent years he had followed a bourgeois "expert" in order to pursue personal fame and wealth and failed to get an achievement in seven years of research. The revisionist route separated him from the mass of workers and peasants. He also mentioned that he wanted always to follow Chairman Mao and strive on the road with the workers, peasants, and soldiers. As workers were encouraged to participate in enterprise management, "the theory of expert-run factory" proposed by Liu Shaoqi (刘少奇) had been severely criticized. Tangshan steel mills raised significant criticisms of the counter-revolutionary, revisionist technical route, which not only ruined the technical authority of the capitalist class, but also established "science and technology management committees" to replace the original expert-run mode. Meanwhile, the number of engineers and technicians who were downgraded and punished due to political error increased. The technical appointment system came to a full stop. Distribution according to work, exchange of equal value, profits and bonuses that were conducive to the development of productive forces were condemned as bourgeois. Bonuses for employees and other perks were distributed in an equalitarian way. Wage levels were set in an unjust structure. Few senior engineers continued to be well paid, and the wage of junior scientific and technological personnel was nearly identical to that of other workers. In 1971-1972, low wages were adjusted. Therefore, most of the engineers depended on low wages to meet their families' basic needs for 15 years or a longer period. The leading cadres at the grassroots level were considered as followers of the Liu Shaoqi Line, spearheading material incentives and profit. Reasonable rules and regulations, and necessary reward systems were abolished. Meanwhile, offering resources for workers and peasants had an impact on other investments that were likely to get the desired results. This enterprise management, that overstressed political means, resulted in a drop in production quality because the information and procedures needed by the planned economy were lost, and enterprises were apt to because a loose organization with no rules. Figure 2.4

Figure 2.4 The Comparison of the average wage between mental and manual workers, 1952-1976[110]



2.2.4 Mobility of engineers

University graduates in this period were divided into two parts: one of which graduated during 1966 to 1971, entering university before the Cultural Revolution. In the course of the Cultural Revolution, there were 670,000 graduates. Affected by the Cultural Revolution, some students were assigned jobs after learning basic courses and as part of professional courses, while others who did not finish basic courses also got jobs. The other part that was introduced or selected to enter universities after 1970 was 'workers-peasants-soldiers-students'. There were more than 800,000 graduates who went to college during the Cultural Revolution. There were a few graduate students who entered

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[110] Source: 朱庆芳，陈云芳：我国知识分子的经济状况。困境与出路：知识分子经济政策研究。北京：春秋出版社。1989。Fang Zhuqing & Yunfang Chen: Economic situation of intellectuals. Problems and Solutions: Intellectuals Economic Policy Research. Beijing: Spring Press. 1989: 87-98.

universities before the Cultural Revolution.

On June 20 1967 the central government issued "The Notice about Distribution of University Graduates" which decided to postpone distribution of the class of 1967. The Notice requirements were as follows:

1. Graduates' distribution must thoroughly break the old system whereby only college and university graduates could be assigned to cadres but not workers or peasants.

2. Graduates' distribution must adhere to the principles of rural areas, the frontier, and the grassroots, combining workers with peasants. The postgraduates in 1966 and 1967 (including graduate students) must be engaged with ordinary farmers and ordinary workers first. Distribution focused on the three-line construction, national defense industry, primary industries, agricultural mechanization, secondary schools as well as the grassroots cultural and educational departments. Those who were assigned to farmers, would be arranged to attend to state-run farms built by the people's liberation army, local and central government in line with the reality. According to the requirements of the country, graduates assigned to be primary and secondary school teachers and medical workers must perform manual labor.

3. Although the class of 1967 was assigned to enterprises owned by the people or work under collective ownership, their wages were given according to the original standard before the wage system reform. In addition to income from the collective economy, graduates working in enterprises under collective ownership could get state subsidies to meet the original graduates' wage standard.

During the Cultural Revolution, the distribution of the 'workers-peasants-soldiers-students' was determined by the principle of graduates coming back to the original institutions according to the national education conference in 1972. Graduates were assigned to return to original institutions in accordance with the initial enrollment plans. Those who couldn't apply their knowledge to their original institution were adjusted by the relevant provincial and regional departments. Those from communes returned to the communes after graduation in line with the plan. The state supported peasants and workers to be graduates. After getting the approval of related departments, they registered in the personnel department above the county level and were accompanied by the educated urban youth to work in the countryside. The labor departments allocated their detail work. The local peasants were arranged in the management of educated youth. The sending enterprises submitted the central government to arrange students who had particular majors, like an atomic energy major. Some graduates strictly implemented the policy of going back to where they came from, which took no consideration of national needs and students' majors.

In addition to the "go to the countryside" campaign, participation in Third Front construction was the other main reason for many engineers to transfer in the Cultural Revolution period. From the mid-1960s to mid-1970s, the Third Front construction was the strategic adjustment combat readiness under specific historical conditions.

In December 1964, according to the policies of "the first front adjustment and the third front construction" and "sudden attack prevention" proposed by Mao and the central government, the national science and technology commission submitted "The Report on the First Front Adjustment and the Third Front Contribution of Natural Science Institutions". The report put forward the first construction plan of layout adjustment for the research institute with a total of 65 projects. The launching of many larger projects caused many demands for the engineers. The Chinese academy of science and 15 ministries of the State Council transferred 20,000 people (accounting for 18% of the total) and the corresponding laboratory equipment from the first area to the third area. About 15,000 people, accounting for more than 70% of the transferred people, were from Beijing and Shanghai.

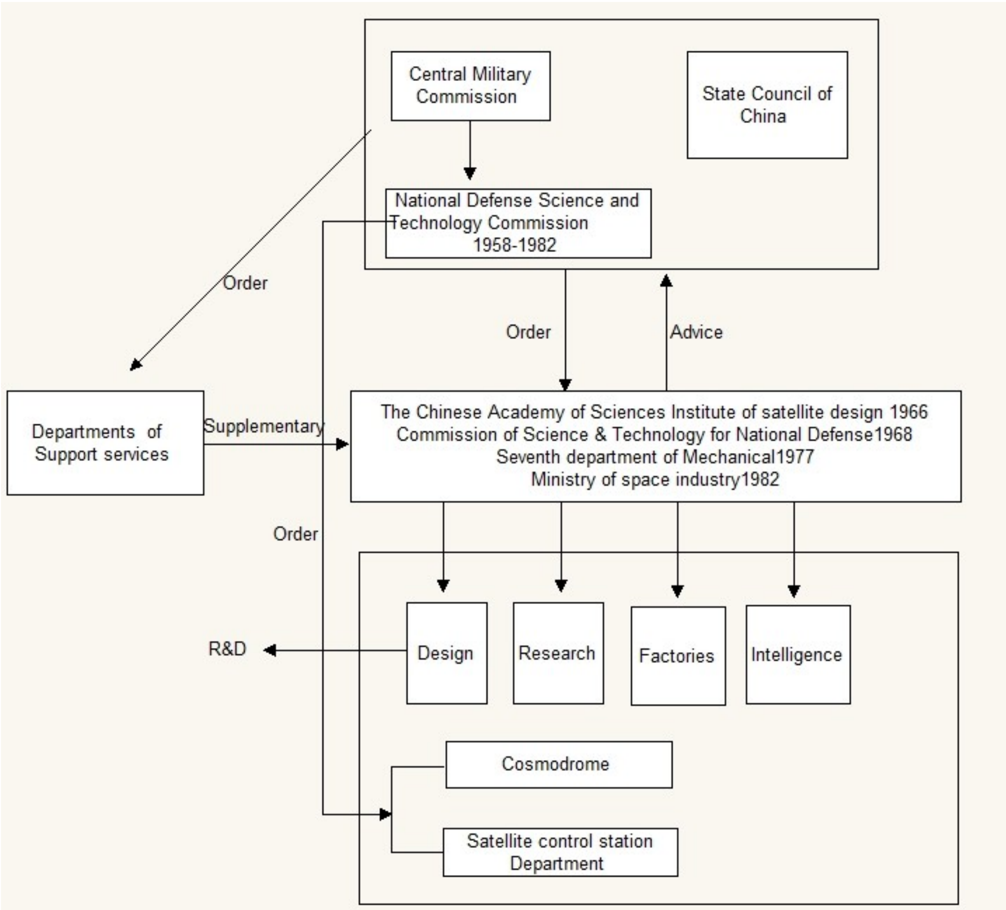
From 1964 to 1975, there were about 380 projects, in the metallurgical industry, the machinery industry, railway and highway traffic, the electronics industry, the aviation sector, the aerospace industry, the nuclear industry, the ordnance industry, coal, petroleum, chemical, shipping and textile, and 145,000 employees and more than 38,000 sets of equipment moved from the coastal area to inland. 2,900 new sets of equipment were installed in an area of 17.2 million square meters, and 124 large and medium-sized projects were built at a total investment of 6.944 billion Yuan. For example, in 1965, the *China State*

Construction Engineering Corporation got the approval of *State Development and Reform Commission* and *the Ministry of Labor* to transfer 11 construction companies and 24,000 employees from 10 provinces (Beijing, Hebei etc.) to the southwest and northwest areas. By 1975, it had fixed assets of 11.201 billion Yuan, including the relocation project. The number of workers increased from 327,600 to 1,175,100 over ten years (1965-1975). Due to the Third Front construction scheme being mainly composed of the national defense industry, the demand for engineers and technicians soared. Many engineers and technicians had to relocate their families to support Third Front construction. In the 1960s, a number of scientific and technological personnel flew into the third area to make outstanding contributions to the development of the area and to ease the imbalanced distribution between the eastern and the western regions of China. In the Third Front, new industrial bases were formed in Deyang of Sichuan province, Chongqing, western Hubei, Hanzhong of Shaanxi province, Tianshui of Gansu Province, Guiyang, Xining, and a large number of small and medium-sized industrial towns came into being.

2.2.4 The China Model: a case of 'Two-Bombs, One-Satellite' Project

In the 1940s, the United States first mastered atomic weapons; by the 1950s, several major world powers had entered "the atomic age" and "the rocket age". In the middle of the 1950s, with the help of the Soviet Union, China took atomic energy as a key national science and technology project. Atomic energy research was of great significance for the CCP, as it embodied national independence. After 1960, the Soviet Union stopped providing technical assistance. With the slogan of independence and self-reliance, Chinese engineers were faced with a bigger challenge that encouraged them to make the most of their wisdom to make progress in technology under the system of Chinese scientific research.

Figure 2.5 The collaborative research institution system



"Two bombs and one satellite" was led and organized by top administrative officials. From 1956 to 1966, Nie Rongzhen (聂荣臻) was not only in charge of national science and technology, but also he was also the vice premier of the state council and vice chairman of the central military commission and the director of the national science and technology commission. As it were, he integrated scientific leadership work throughout the country. Nie Rongzhen took overall responsibility for the whole project and reported directly to the central specialized committee and the central military commission. To ensure the progress of research work, the central committee coordinated and solved the relevant problems. In 1960, the central committee approved the report about adjusting the 'technical backbone' and college students needed by relevant scientific research departments as soon as possible, which was applied by Zhang Aiping. The central secretariat issued a special circular that required the ministers of the provincial and regional organization to take responsibility for choosing talent to meet demand. They ensured the implementation of the task quickly. There were 100 technicians with practical experience, 4,000 college students and 2,000 graduates from polytechnic schools that joined the national defense scientific research team.

In 1962, a central specialized committee was set up and Zhou Enlai as prime minister organized and coordinated research into sophisticated weapons. When it came to cooperation among all provinces and departments, it was necessary to appoint senior officials and to carry out a responsible system to ensure continuous and clear command (Figure 2.5). Under the senior centralized leadership, they took advantage of all their national scientific research strength to coordinate and solve the problems of the process of the development of atomic technology, including the Chinese Academy of sciences, institutions of higher learning, industry, national defense, scientific research institutions and local research organizations. They also regulated national instrument manufacturing and production processing to provide tools and equipment for the second of the seventh machine departments. Meanwhile, all kind of departments which could be involved were organized, such as the ministry of communications, the civil aviation department, the ministry of public security, ministry of posts and telecommunications, ministry of commerce, food department, ministry of foreign trade, the department of materials, water and electricity department, the ministry of health, environmental protection bureau and the general logistics department, and so on.

According to preliminary statistics, in the process of development of the first atomic bomb, more than 900 factories, scientific research institutions and institutions of higher learning of 26 national departments located in 20 provinces, autonomous regions and municipalities worked together to perform scientific research, equipment manufacturing and produce materials. The size of the collaboration was reflected in the internal work. The cooperation in the nuclear industry was embodied in every link, such as geological exploration, mining, industrial production, weapons development, scientific research, equipment manufacturing, construction, transportation, communications, security and protection. In accordance with the deadline to realize the general objective of a nuclear explosion, every link devolved tasks, systems and aspects to all departments. Qian Xuesen recalled: “China had never made large-scale science and technology research in the past. “Two bombs” was a large-scale science and technical research project that need the collaboration of thousands of people. China had never done that before. Figuratively speaking, when we were doing experiments, we occupied nearly half of the national communications lines. We can see its scale.”[111]

This top-down administrative system of scientific research was able to continue to undertake “two bombs, one satellite” unaffected by politics even after the outbreak of the Cultural Revolution in 1966. In 1966, plagued by power battles and infighting, factories almost stopped production, but “two bombs, one satellite” was protected by senior leaders as a national project. In order to reduce its impact, from November 1966 the military gradually controlled the 701 engineering departments of the Chinese Academy of Sciences and the seventh machine department. In 1967, the nuclear industry practiced martial management. From March to November 1967, Mao Zedong, Zhou Enlai, Ye Jianying, Nie Rongzhen and other senior leaders sent 22 telegraphs to central factories, research institutes and construction sites which required people to play politics in their spare time as well as not to seize power, or in fight so as to guarantee absolute safety and steady production.

Due to the political importance of “two bombs, one satellite”, the project was even protected with special treatment in difficult times, unlike civil engineering that had to halt for lack of funding. In 1967, the expenditure of the Chinese Academy of Science was only 16% of that in 1965, but the expenditure of “two bombs, one satellite” project soared sharply, for example, the basic construction investment of the nuclear industry was required to complete the total amount of construction of the previous 15 years in the period of the fourth Five-Year Plan.[112]

Some scientists and engineers had privilege and could have direct dialog with senior leaders, such as Qian Xuesen (钱学森), Qian Sanqiang (钱三强), etc. They could rely on their high fame to select people unaffected by the political environment. For instance, Qian

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[111] Jin, Chongji, A biography of Zhou Enlai, Volume 4,Chinses Literature Publishing House,1998:1748.

[112] 沈传宝：《科技强国，永垂青史——“两弹一星”座谈会纪要》，《中共党史研究》2001年第1期。Shen Chuanbao: the seminar of “ two bombs one satellite ”, Chinese Communist Party History Research. 2001.

Sanqiang broke a rule to engage Yu Min, who was criticized for striding on "Expert Roads" to participate in the pre-study of the hydrogen bomb. Because of sensitive overseas relations, Zhou Guangzhao suffered from unfair treatment even in his department, but Qian Sanqiang made an exemption to hire him. Both of them became medal winners for meritorious service.

Strongly centralized political control provided the necessary material support for "two bombs, one satellite". In the view of technology problem, most of the hard-nut problems were tackled by imitating and improving products from abroad.

For example, in June 1958, the Soviet Union shipped samples, drawings, process planning and molds of the P-2 missile that was the revised product of a V-2 missile used by Germans in World War Two. In January 1959, after two years of learning and stimulating, China had mastered the missile test technology. In 1960, the relationship between China and the Soviet Union deteriorated. On August 24, the Soviet Union withdrew all experts from Chinese bases, and the central committee decided to develop missiles on their own. In the absence of further technical and equipment support, and on the basis of previous technical support offered by the Soviet Union, the engineers improved their focus and tested the propellant technology of the Soviet Union experts.

On September 10 1960, the first generic missile was launched. Afterwards, through the study and improvement of P-2 missiles, its range became twice as long as short-range missiles. In 1962, the missile took its first test flight, with errors in the overall design causing test failure. The engineers convened a meeting to discuss the problems exposed by the test. Tu Shou'e (屠守锷), aerospace engineer, the head of the overall design department, presided over the meeting, and electromechanical engineer Liang Sili (梁思礼) and mechanical engineer Xie Guangxuan (谢光选) attended it. They discussed the overall design and made corresponding improvements. Later, under the auspices of mencahnical engineer Ren Xinmin (任新民) who was the director of the liquid-rocket engine design department, they not only enacted technical measures improving the seismic performance of the engine structure, but also proved that these measures were reasonable through a lot of ground tests. In June 1964, the revised "Dongfeng Ⅱ" missiles had a successful launch, which marked the development of China's missiles from imitation to the self-design stage. In 1966, guided missiles were combined with an atomic bomb flight test. In 1970 intermediate-range missiles and intermediate and long-range missiles completed flight tests, and the long-range missiles were finished in 1971 successively.

With the success of "two bombs, one satellite", the Chinese model of an organizational and administrative approach to science and technological presented its unique characteristics. Centralized political control guaranteed the implementation of key projects. However, all these achievements consumed large amounts of resources through administrative organization and arrangements. The arrangements avoided the effect of ideological and political disputes, which was undoubtedly successful in the historical environment. However, the change of the historical environment exposed many shortcomings of the Chinese model. The main body of technological innovation was the government, and enterprises had no ability or incentive to carry out technological innovation, because most scientific and technical personnel were concentrated on specialized scientific research institutes. Although science and technology research institutes with the most technological resources could study new techniques and equipment, apart from key projects designated by the state this new technology and equipment could not meet the requirements of enterprises because of the lack of contact with the enterprises. Even if new technologies met the enterprises' needs, they could not realistically turn into being productive because research institutions had no impetus. Thereby, large state-owned enterprises paid more attention to the introduction of the operation of the equipment and developing the production capacity of existing equipment, and required more technical personnel than engineers. These problems were the main reasons for the reform of 1978, as we shall see.

2.3 Engineers in the Reform period, 1978-1989

The Third Plenary Session of the 11th Central Committee of the NPC in 1978 ended the political line of "class struggle" begun in 1956, and established the new line of "taking economic construction as the central task". The policy of transferring the Party's general goals and tasks from transforming society and people to developing the material economy caused corresponding changes in elite policy.

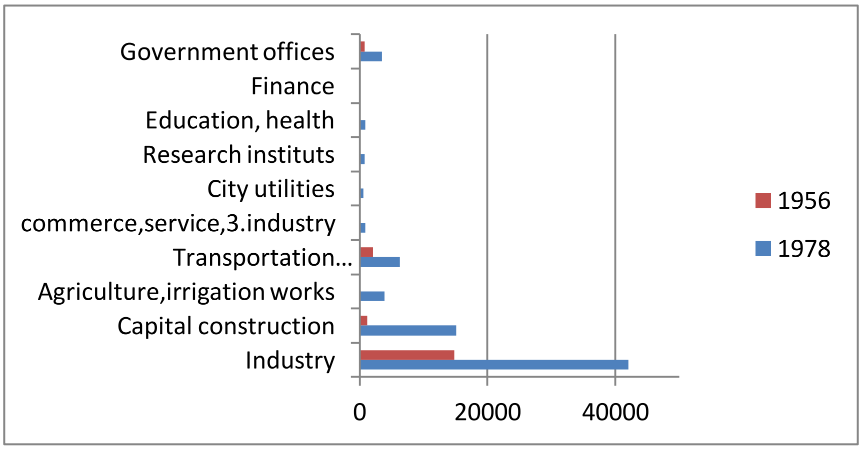
2.3.1 Data on scientific and technical personnel

According to the report of the Xinhua News Agency on June 23 1978, the State Planning Commission, the National Science and Technology Committee, the Ministry of Civil Affairs and the National Bureau of Statistics decided to investigate the status of scientific and technical personnel so as to have a comprehensive understanding of their quantity, educational background, distribution, and work situation. With the commencement of this work, China carried out a census on scientific and technical workers including engineers, the elaborate degree of which was higher than any population or occupation census in history. Based on this, we can better understand the construction, professional scope, qualifications and proportion of female engineers in China for the first time.

The number of scientists and engineers with higher education was about 1,571,000 in 1978, an increase of 1,400,000 on the levels of 1952 (164,000). 4.7% of them received intermediate or senior professional titles, that's to say, the number of engineers was about 73,837. Despite the unfair treatment of intellectuals during the ten years of the Cultural Revolution, the number of engineers increased remarkably. According to the occupation census carried out in 1978, the four fields - namely industrial enterprises, state departments, the construction industry and infrastructure - were comprised of more than 90% engineers. Among them, industrial enterprise was a field that required more engineers than others.

Only 5% of engineers worked in state departments, from which we can know that there were rare engineers who worked in state departments after the Cultural Revolution. The number of engineers in the construction industry was second to industrial enterprises. The number of engineers in state-owned infrastructure including transportation, the postal service, and the telecom industry was about 6,269; while engineers in the service industry and the tertiary industry was very few.

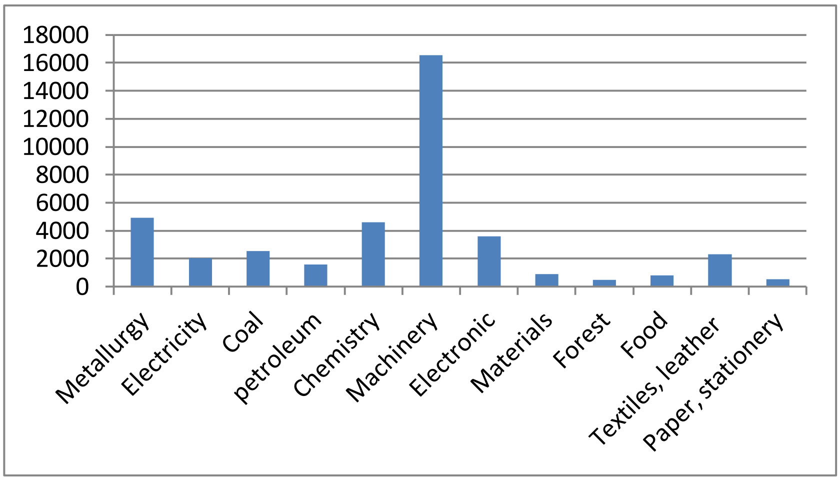
Figure 2.6 Number of engineers working in the field of science and technology in state-owned institutions[113]



From Figure 2.6, it is clear that the distribution of engineers in industrial enterprises in 1978 was unbalanced. Engineers in raw material and heavy industry sectors made up three-quarters of the total number since heavy industry sectors were the development object of the government's key economic policies in the last four Five-Year Plans, while the proportion of engineers in the mechanical industry accounted for 40% of all industrial enterprises because of the requirements the Cultural Revolution placed on the military. Comparatively, engineers in the textile industry and the production of food and daily necessities were rare due to their low technology levels, which was also one result of the industrialization of heavy industry.

[113] The data published in 1978 detailed the number of scientific and technical workers in state-owned units. Senior and intermediate engineers accounted for 0.5% and 4.2% of the scientific and technical workers respectively. People with above intermediate professional titles were engineers, people with junior professional titles were assistant engineers. Therefore, engineers made up about 4.7% of scientific and technical workers. The statistical data in 1956 referred to the data of China's science and technology in the previous 40 years(336).

Figure 2.7 The distribution of engineers in industry sectors



Of all engineers, 4.2% had an intermediate professional title (engineer), and 0.5% had a senior professional title (senior engineer), which was a small proportion of all engineering technicians. 95.3% of engineering personnel were given a junior professional title. This had a close connection to the abolition of the evaluation system of professional titles during the Cultural Revolution. At the end of 1988, the proportion of engineers with intermediate or senior professional titles quickly increased to 25.4% and 5.6% respectively; while the percentage of junior assistant engineers decreased to 69%.[114]

Moreover, in 1978, among 10,000 workers, 10 were engineers, which doubled the 1956 number. For China, a country with a big population, the data was more illustrative. It was clear that the proportion of engineers in work was small. Of the current engineering technicians, 43% received higher education (1/3 of whom graduated during the 10-year prolonged turmoil of the Cultural Revolution, when education suffered greatly). In this group, engineers under 35 years old were badly needed.

According to the occupation census of 1978, we can draw several conclusions about the vocational status of engineers after the Cultural Revolution. First, the number of engineers still maintained a tendency of growth; second, the 10-year long Cultural Revolution resulted in a great unbalance in the number of engineers in industrial enterprises and an unreasonable distribution of engineers, with too high a proportion in

[114] China Statistics Bureau: Science and Technology Statistics Division: Statistics On Science and Technology of China 1949-1989,Beijing: China Statistics Press, chart 4.

heavy industry sectors; third, following the unfair persecution of intellectuals during the Cultural Revolution, the number of engineers who engaged in planning and research in government sectors was decreasing, causing the country to lack corresponding talents when formulating economic and industrial development plans and a deficit of scientific management in companies and the government; and fourth, the proportion of engineers in the pool of scientific and technical workers and the overall number of workers was very small.

2.3.2 Policy adjustment

According to Li Guoqiang's study of Elite Decisions and Political Reform in China, some foreigners predicted as early as the 1970s that China had only two choices after Mao Zedong died. One was the Stalinist path, that is to say, to break the messy situation resulting from the Cultural Revolution with highly centralized political power and to intensify control in all areas of society; the other way was to adjust the rigid political and economic system, to follow the path of reform and to look for external and internal support. After suffering the Cultural Revolution, since the Stalinist way had lost its attraction, the collective leadership of Deng Xiaoping chose to reform socialism.[115] As an external support, intellectuals, who had suffered a lot in the Cultural Revolution, welcomed the new policy without hesitation. From the view of engineers, the biggest change brought about by the new policy in 1977-1978 was that people abandoned their radical opinions towards science and technology. When the importance of professional knowledge and the requirements of producing professional knowledge were recognized, the standard of engineers and their importance received attention unprecedented since the mid-1950s.

After 1977, the CCP made significant efforts to re-attract engineers, including rehabilitating the reputation of engineers who were labeled as rightists in the Cultural Revolution, restoring their titles, redistributing those who were engaged in physical labor,

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[115] Li,Guoqiang: Elite Decision-making and Political Reform in China .Cite: Xu, Xianglin: political reform political parties, government and society. Zhongxin Publishing House.2004:85-94.

and so on.

Elite engineers took part in formulating national macro-economy and technology plans again. The newly-established National Science and Technology Committee held a nationwide science and technology planning meeting in Beijing from December 12 1977 to January 16 1978 and set up the Nationwide Science and Technology Planning Meeting from 1978 to 1985, the Eight-Year-Long Science and Technology Planning for short. The planning put forward four goals for China's science and technology works in the following 8 years: 1) for important fields of science and technology to get close to the advanced world level of the 1970s; 2) the number of professional scientific researchers to increase from 360,000 to about 800,000; 3) for the country to possess a group of modern scientific research bases; 4) for the country to establish a national science and technology research system. In order to push the development of science and technology and the national economy, the Eight-Year-Long Science and Technology Planning directive gave priority to the development of eight comprehensive science and technical fields - agriculture, energy, materials, electronic computers, lasers, space, high-energy physics and genetic engineering, major emerging technologies and leading subjects. The plans were the result of discussions between scientists, engineers and experts in scientific management in the two meetings. However, because the scientists and engineers were eager to revitalize the country through science and technology and were anxious for success, their indexes were excessively high, and they were too impatient for development. For example, they planned to build 120 large industry projects, including ten iron and steel bases, nine non-ferrous metal bases, eight large coal bases, ten large oil-gas fields, 30 large power stations, six new trunk railways and five major ports. Besides, they required the production of steel reach 60,000,000 tons in 1985. All these unrealistic production targets were adjusted in practice. Energy and industry projects were still the key projects in national economic construction, which was reflected in the 65 and 75 plans for tackling key problems. Most key industry projects learned from and developed sophisticated foreign technology, including complete sets of equipment and key technology and equipment.

After the third plenary session of the 11th central committee, the CCP Central

Committee established the policy of "readjusting, restructuring, consolidating and improving", China's economy, determined to downsize the scale of capital construction, and readjusted the severe imbalances in all areas. The reform of the scientific and technological system was imperative. From 1980 to the end of 1984, the country underwent a pilot exploration within the science and technology system, including founding a R&D production association, rewarding technological achievement with compensation, implementing a technology contract system and freely combining research groups within R&D institutions.

1985-1988 witnessed the comprehensive reform of the scientific and technical system. In the aspect of operating mechanisms, the country changed the appropriation system, developed the technology market, and overcame the habit of managing scientific and technological works through administrative measures only. In addition, the country applied economic market levers while managing national key projects; in organizational structure, the state changed the separation between research institutions and enterprises, the divorce of study, design and education and production, the segregation of soldiers and civilians, regional divisions, and took active measures to enhance enterprises' capacity to absorb and develop technology, and strengthened the transformation of technological achievements and their application in production. In the personnel system, the country turned the situation around including reversing excessive restrictions on scientific and technical workers, the irrational flow of talent and the disrespect shown to intellectual works. This was aimed at shaping a favorable environment in which people of talent were developed in succession and everybody was allowed to fully display their ability.[116]

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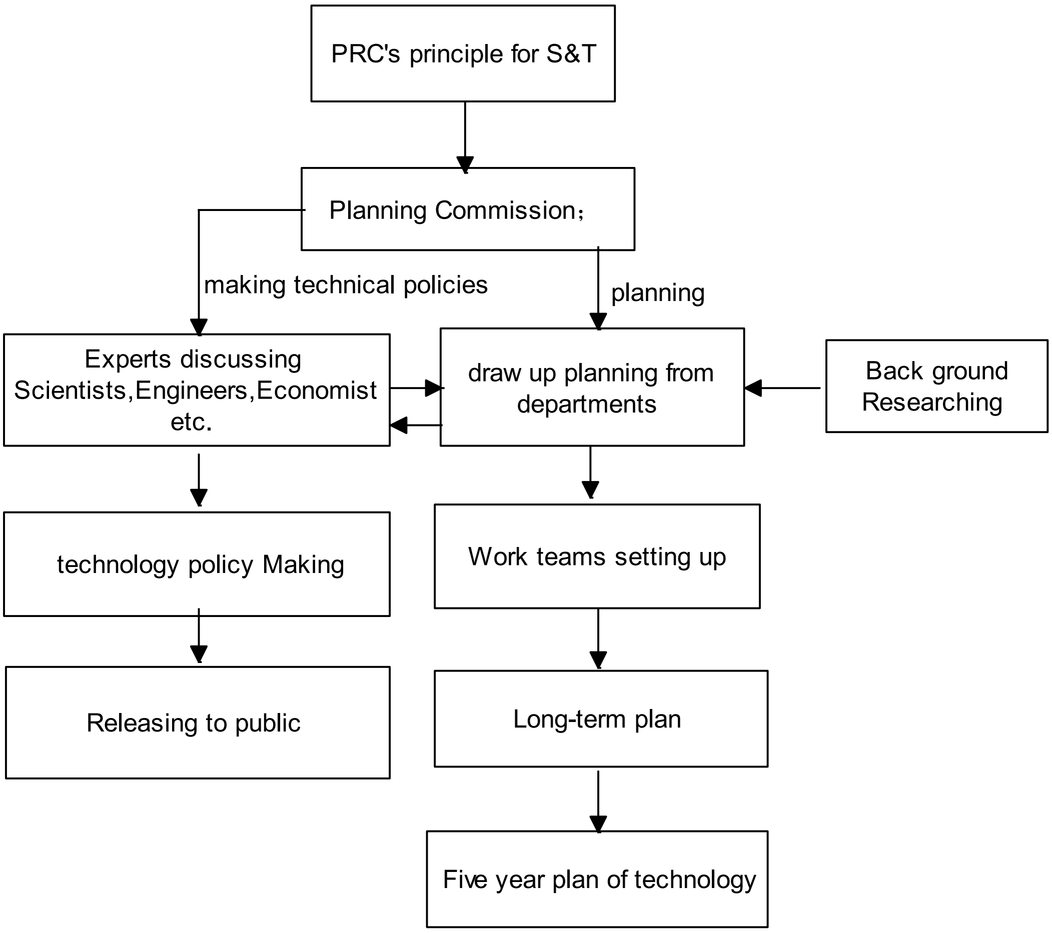
[116] CCP Central Committee on Science and Technology Reform

Figure 2.8 The PRC's principle to formulate scientific and technological development plans



2.3.3 The new formation of an engineers' framework

In the 1980s, some countries, including America, started to establish an international mutual recognition system for engineering education and engineers, which mainly included the standard of engineering education and further study, the certification of institutions, as well as the certification of educational backgrounds and qualifications for engineers. The current six agreements of the system can be divided into two levels which were in a causal relationship: The Washington Accord, the Sydney Agreement, and the Dublin Agreement were particular to the recognition of all kinds of technical engineering education, and the Agreement of Engineers' Mobility Forum, the Plan of Engineers in Asia-Pacific Area and the Agreement of Engineering Technicians' Mobility Forum were unique to the recognition of the practicing requirements of various engineering technicians. In the 1990s, Asia contributed to the work of engineering recognition through the Plan of Engineers in

Asia-Pacific Area, but Hong Kong was the only area in China that was involved in the plan. From the 1980s to 1990s, Chinese engineers conducted occupational reform and adjustments. To attain international standards, China made great efforts that were as follows.

2.3.3.1 Training of engineers

In January 1980, the Ministry of Education replaced the engineering courses' training objective of cultivating "common workers" in the Cultural Revolution with "receiving fundamental training specific to engineers".[117] To meet the Chinese economic system's need for reform, higher engineering education also made corresponding adjustments and reforms, which mainly included the following aspects:

1. Restructuring recruitment plans. The recovery of the national unified entrance examination system used 66 years ago. Anyone who wanted to be a scientist or engineer did not need to have work experience before entering college or university and be recommended by the company he/she worked for, as before. Political investigations, which were the decisive factor in whether someone could enter into colleges or universities, were replaced by academic standards. Since graduates of previous years had the right to take college entrance examinations, in 1977, 5,700,000 took the examination, among whom 270,000 were enrolled (76,000 were engineering majors, accounting for 28%); in 1978, of the 6,100,000 students taking the examinations, 402,000 were enrolled; during 1977-1981, the admission rate was about 10%, and after 1982, since most students were fresh graduates, the admission rate was 20%-30%.

2. Dividing disciplines. In 1980, engineering majors in the whole country could be classified by name into 664 types. By combining majors of the same intention but of different names, the country could set 534 majors, among which a small part were divided into subjects with a wide range, while most were classified according to industry, product or engineering objective. In 1989, the Catalogue for Undergraduate Engineering Majors in

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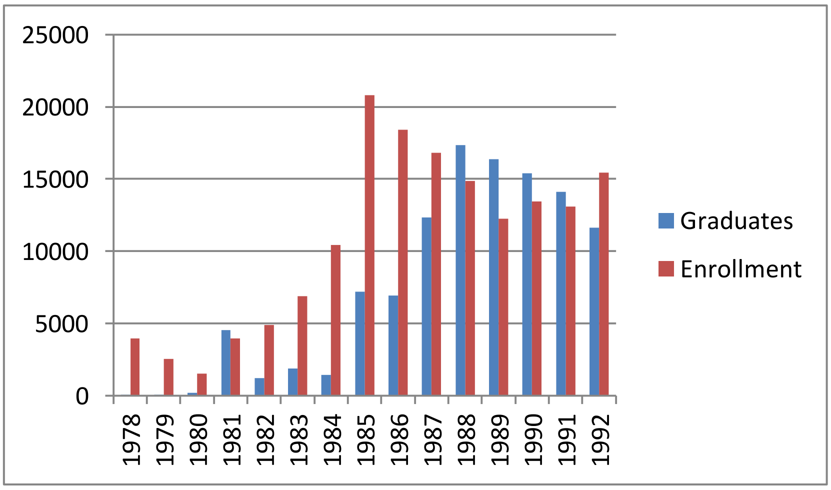
[117] Liu,Yingjie: China Education events1949-1990.Hangzhou:Zhejiang Education Publishing House.1993:196.

China's Colleges and Universities was amended, which made it clear that the number of undergraduate engineering majors in 1989 would decrease to 125 (in 1980, the number was 534) in order to improve engineering graduates' adaptive capacity to their work in future.

3. The hierarchical structure of engineering education. In October 1977, the State Council endorsed the Opinions on Colleges and Universities' Recruitment of Postgraduates of the Ministry of Education, which recovered postgraduate training that had been suspended for 12 years. In 1980, Degree Regulations of the People's Republic of China were issued which said that academic degrees could be divided into three levels - bachelor, masters, and doctorate. Different academic degrees had different requirements, for example, undergraduate education lasted for four years and full-time postgraduate education 2-3 years; the education period of on-the-job postgraduates could be one year longer; the education of full-time doctoral students lasted for 2-3 years; the education period of on-the-job doctoral students could be one year longer.

Figure 2.9 The enrollment and graduation numbers of postgraduates and doctoral students in China during 1978-1992

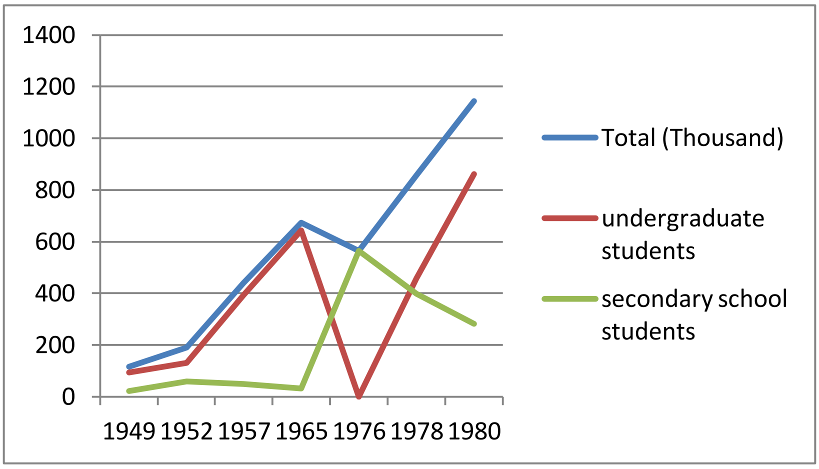


Sources: The Ministry of Education: the statistical data of China's educational achievements during 1949-1983. Zhang Guangdou, Wang Jisheng. Higher Engineering Education in China, Beijing: Tsinghua University Press, 1995.

4. The reinforcement of education in higher engineering colleges. Since the founding of the nation, education in higher engineering colleges in China had been a temporary measure to meet the need for talented workers. After 1977, education in higher engineering colleges received more attention. Since people cultivated through engineering education were unitary, for a long time they were used to meet the needs of all social construction

works, resulting in an irrational use of people. Industrial producers still needed a group of technicians and field engineers who had received training in higher engineering colleges to manage daily production and solve general engineering problems. Based on knowledge recieved in high school, junior college students studied basic college theories and did engineering practices that placed particular emphasis on the application of engineering. When graduating after two to three years, they could receive an associate degree and a professional certificate. With the support of national and local policies, various higher vocational schools were founded, which to a certain degree alleviated the pressure on college graduates to enter colleges.

Figure 2.10 The number of undergraduates and secondary school students since the foundation of the PRC [118]



Source: Zhang Guangdou & Wang Jisheng eds.. Higher Engineering Education in China, Beijing: Tsinghua University Publishing House, 1995.

5. The expansion of colleges and universities' decision-making powers. In 1985, our nation paid attention to colleges and universities' autonomy in running schools, which started the first round of reforms of the higher education management system, making it clear that colleges and universities had decision-making powers in six aspects, namely teaching, research and development, enrollment, personnel, finance and international exchange. To put these principles into practice, in 1986 the State Council issued the Provisional Regulations about Colleges and Universities' Education and Management

[118] Graduates were considered secondary school students in the Cultural Revolution period.

Responsibilities which expanded the range of their decision-making powers.

6. The dispatch of overseas students. The country formulated a new study-abroad policy. When the Cultural Revolution began, studying abroad was stopped. In 1978, Deng Xiaoping indicated in a meeting that he agreed to increase the number of overseas students majoring natural science, arguing that it would have a positive effect in five years, and was an important way to strengthen our country. He argued that we should send tens of thousands of students instead of only a few. At the end of 1978, China's first group of 50 overseas students arrived in America, starting the boom of sending a lot of students to study abroad in the new period. In 1980, the country set up the policy of guaranteeing quality and striving to send more students. In 1981, the policy of studying abroad at one's expense further increased the numbers. The dispatch of overseas students was a significant way of cultivating senior scientific talent.

2.3.3.2 Occupational conditions

After the 1980s, the occupational conditions of engineers changed gradually. Engineers' inability to work freelance reflected the nationalization of the position. However, after the 1980s the country allowed scientific and technological workers to have other part-time jobs and encouraged them to be freelancers to some degree. According to the survey conducted in 1986, there were 118 engineers in Shanghai who left their companies to be freelancers, among whom senior engineers accounted for 10%. By 1993, the number of freelance senior engineers was 110, accounting for 33.7%. Many people started their own science-and-technology enterprises, including Fan Chonghui (范崇惠), chief engineer and professor in Shanghai Academy of Sciences, and Ruan Xueyu (阮雪榆), a professor in the University of Communications. The "Spark Plan" (星火计划) relied on scientific and technological progress to revitalize the local economy, and also contributed to a large number of engineers leaving the countryside, contracting township enterprises. At the end of 1987, there were about 360,000 scientists and technicians had involved in "the implementation of the Spark Plan".

2.3.3.3 Professional title system

In 1978, the national conference on science and technology put forward the spirit of "recovering professional titles and establishing a system of job responsibility in technical posts". In 1979, the evaluation of the professional titles of mid-level officials and the titles of professional cadres was officially started. The professional title assignment system implemented in the 1950s evolved into a professional title evaluation system. The title of engineer could indicate the level, capacity and work performance of engineering technicians. Evaluated by experts, the engineer had no job requirements, quantitative limitation, or term of service. Once someone had the title, he/she could have it for life. It was more like a certification that could approve your technical or engineering ability. However, the wage standards were linked to titles.

To be more precise, from the aspect of the quality of engineers, China has no special engineering evaluation system; engineers are evaluated according to the existing professional title evaluation system. Professional titles can be classified as senior professional titles, intermediate professional titles or junior professional titles. People with junior professional titles are equal to associate engineers, and persons with middle and senior professional titles are considered as engineers and senior engineers. The professional title is evaluated by the unit the candidate belongs to. The evaluation committee and leaders of these units takes charge of the evaluation. During the evaluation, the engineer's educational background, professional skills and work performance are considered. However, as there are no quantified standards for different units at national level, there is a big difference between engineers in levels of quality. A standard, unified, strict, open and transparent engineering evaluation procedure has yet to be formed. How to formulate a socialized and professional management system assumed by professional organizations to standardize engineers' occupational requirements is an issue in urgent need of discussion.

2.3.3.4 Engineering organization

After the third plenary session of the 10^{th} CCP Central Committee, elite engineers' reputations gradually recovered in the Association for Science and Technology. Furthermore, engineers actively took part in CAST and its activities. In the list of the second president, vice-presidents and standard committee members in CAST, the number of engineers was 11, accounting for 27%. In the list, the president was authority astro-engineer Qian Xuesen (钱学森), and the number of engineers was 19, making up 32% of the total. Some elite engineers such as Qian Xuesen, Song Jian, and Mao Yisheng, had significant positions in the Science and Technology Committee and the Association for Science and Technology; meanwhile, they were also given the support of the Central Committee of the CCP.

After 1977, national professional engineering societies restarted their academic activities in succession under the leadership of CAST, including the Chinese Society of Aeronautics and Astronautics, the Chinese Society of Naval Architects and Marine Engineers, the Chinese Institute of Electronics, the Chinese Ordnance Society, the Chinese Association of Agricultural Science Societies, the Chinese Society of Theoretical and Applied Mechanics, the Chinese Society for Metals, the Chinese Society of Forestry, the Geographical Society of China and the Chinese Mechanical Engineering Society. After the 1980s, CAST and various professional engineering associations devoted themselves to the regulatory reform of engineering quality. As authorities within the industry, some associations awarded engineers professional qualification certificates accepted by the industry together with the Ministry of Personnel in China, to promote internal communication and mutual recognition of the industry.

Since the 1980s, China has attached great importance to science and technology, engineers have been widely recognized by society again, and their occupational pride has increased. A group of engineers were widely advertised as role models, such as Hua Yi, an engineer in the China Shipbuilding Corporation, Jiang Zhuying (蒋筑英), an associate researcher in the Changchun optical machinery research institute of the Chinese Academy of Sciences, Luo Jianfu（罗健夫）, an engineer in the Li-Shan Micro Electronics Corporation in Shanxi, and so on.[119] Although these role models were created out of

[119] 痛惜之余的愿望。人民日报，1982年11月29日。Hope after the memorial. 29 November 1982.

political need, the common representative engineers have increased people's respect and support for engineers and their work.

2.3.3.5 Legal protection

In 1982, the Community of Science and Technology showed its great concern to the 1982 Constitution, including its draft. The provision in Article 45 of the draft constitution that citizens have the right to perform scientific research, undertake literary and artistic creation and other cultural activities, was very positive. The new constitution considered intellectuals as a support for socialist construction and regarded the task of developing science as an independent part in the general list, which had a considerable influence on scientific and technological circles.

In order to cultivate and use engineering and technical cadres correctly, under the evaluation and promotional work well and give full play to the initiatives of engineering and technical cadres, the National Science and Technology Committee, the Economic Committee and the Bureau of Scientific and Technological Cadres under the State Council worked out the Provisional Rules of Professional Titles of Engineering and Technical Cadres which was carried through by the State Council endorsed it in December 1979. In the same month, the Bureau of Scientific and Technological Cadres under the State Council published "On Several Issues When Performing the Provisional Rules of Professional Titles of Engineering and Technical Cadres". After the decree, an engineering regulation system was gradually restored which made engineering qualifications more standardized. Moreover, an effort was also made on competitive employment, which is different to the job assignment system. In February 1986, the State Council issued "On Regulations of Implementing the Professional and Technical Post Appointment System", which included proposals that the wage should be related on the professional post; the evaluation and regulation of technical post and the duration of employment. This movement was to establish an engineering system compatible with both the socialist market economy and international practices.

Efforts were also made in intellectual property protection. In March 13 1985, the

Central Committee of the CCP issued the "Decision on Scientific and Technical System Reform" worked up drafts regarding "Technology Contract Law", "Scientific Research Institution Law" and "Scientific and Technical Community Law" during 1986-1987. The "Technology Contract Law" declared that technology was a commodity. Thus, companies and individuals could transfer technologies without limitation from regions, departments and economic forms. The regulation freed many people from the traditional thought that since the country provided you with an education, all scientific achievements belonged to the country, and you could not sell technologies as goods. At that time, the regulation was thought-provoking.

2.3.4 Engineers come to power

The massive transformation of the Chinese elite in the 1980s served as the opening of a 'new technocratic era' in contemporary China. In 1978, as vice-premier, Deng constantly claimed that intellectuals should not be treated as an "alien force" but should be respected as the "core of the modernization program".[120] Since the start of the reform of the cadre system, at the beginning of 1980s, Chinese leaders spared no effort to promote political reform. While the CCP, under Mao's regime, was mainly led by soldiers, peasants, and the working class, in post-Maoist China they were all replaced by highly educated scientists and engineers. During a short period of no more than ten years, almost the entire political elite that had obtained crucial positions by relying on their radical ideology and passion for revolution stepped down from the stage, and were replaced by a group of new, young and middle-aged knowledge and technology specialists, most of whom had received good education and trained in science and engineering. In the course of this social transformation, pragmatic technocrats took the place of ideology-oriented Party cadres to become the leading force of China's political and bureaucratic system. Obviously, engineers were beneficiaries of the transformation. In addition, technocrats became

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[120] Cheng, Li & Lynn White: Elite Transformation and Modern Change in Mainland China and Taiwan: Empirical Data and the Theory of Technocracy. The China Quarterly 121, 1990: 12.

synonymous with a management-professional elite in the Party and government leaders at all levels.

According to statistical data from the 27 areas, including provinces, municipalities, and direct-controlled municipalities in 1978 (Table 2.11), leaders holding college degrees numbered only 2%, however in 1984 this number was 51%. Most of the leaders held a junior middle school degree in 1978 (86%), in 1984, this situation had changed, the educational level of the new generation was rising - 51% of leaders had college degrees, and only 25% leaders had junior middle school degrees.

Table 2.10 Changes in Educational level of leaders at the County, Prefectural and Municipal Levels

Educational Level	Percentage	
	1978	**1984**
College	2	51
Senior middle school	12	24
Junior middle school	86	25
Total	100	100

Source: Guang Jiaojing Wide Angle (Hongkong), No.162,16 March 1986:21.The 1978 figures are rounded to the nearest decimal place from those in the source. (as cited in Cheng, Li and Lynn White. 1990. " Elite Transformation and Modern Change in Mainland China and Taiwan: Empirical Data and the Theory of Technocracy". The China Quarterly 121: 1-35)

2.3.5 International cooperation and imitative innovation (taking BaoSteel as an example)

BaoSteel Construction was a typical example of how China's big state-owned enterprises reformed the old enterprise system after the 1980s and were transformed by their introduction to independent research and development.[121] After the Third Session of the 11th Central Committee of the CCP, in order to show the new government's enthusiasm for quick reform, the Central Committee confirmed the introduction of a

[121] Shanghai Baoshang iron and steel plant

group of key construction projects and their primary technical equipment, including 14 key equipment development projects such as developing complete sets of equipment for an open-pit mine of ten million ton, extra-high voltage power transmission and transformation, heavy haul trains in Datong-Qinhuangdao Railway and extensive port ship engineering, 30-ton ethylene plants, large chemical fertilizers and electron-position colliders. BaoSteel was also included. As the biggest industrial project introduced from abroad, it was the first one driving into new times that involved profound reform in technology, economics, talent and ideology.

In the 1980s, Germany and Japan were free from the pressure of post-war reconstruction. Their engineers found that transferring technical knowledge to developing countries was a good way to maintain their economic strength. At the time, China was carrying out the policy of reform and opening up. The new national policies and external technologies brought vitality to large enterprises in China while also challenging Chinese engineers. During the previous ten years, because of the influence of the enclosed environment, Chinese engineers lagged well behind international advanced technologies. When the country opened to the world again, Chinese engineers found that the gap between them and advanced foreign technologies was tremendous.[122]

The BaoSteel Project was prepared in 1977 and started in December 1978 after it was approved by the Central Committee of the CCP and the State Council in March 1978. The design of BaoSteel at the first stage was contracted to Japanese Nippon Steel Corporation. In May 1978 an agreement about Shanghai BaoSteel and the No. 1 Technological Cooperation Contract was signed. The contract indicated that when the Nippon Steel Corporation designed the project, the other part could send technicians to take part in it. To guarantee the continuity and integrity of the project, the Nippon Steel Corporation was responsible for integrated management, production arrangements, training for production technicians, guidance in production technology, and equipment maintenance. In ordering equipments, if the two parties could not reach an agreement on the equipment that

[122] 殷瑞钰，汪应洛，李伯聪等著：工程哲学。北京：高等教育出版社。2007。Yin,Ruijue, Wang Yingluo, Li Bocong : Philosophy of Engineering.Beijing: Higher Education Press ,2007: 301.

Nippon Steel Corporation could make, they could choose other manufacturers and even other countries. As for equipment that Nippon Steel Corporation couldn't make, the Chinese party had the right to choose manufacturers, which changed the situation of purchasing equipment without bringing in technology. Later on, China signed a contract for c140mm seamless tube tandem mills with SMS Demag GmbH (about 10,000-ton auxiliary equipment was designed and supported by Demag and manufactured by the Taiyuan heavy machines plant in China). In addition, China signed a 2050mm hot rolling contract with Japanese Mitsubishi (about 10,000-ton equipment was designed and supported by Japan and manufactured by China First Heavy Industries, China Second Heavy Industries, Shenyang Heavy Industry, and Hec group). A 2030mm cold rolling contract was signed with SMS Siemag AG (acid pickling, cold rolling, leveling and cut-up units were manufactured by SMS Siemag AG; while Siemens made electrical parts). When signing the contract, authorized by the First Machinery Industry Department, the Shanghai heavy machines plant signed a 10-year long technology transfer agreement with Siemag.

However, due to hasty implementation, the required capital of the BaoSteel engineering project surpassed the fiscal capacity of the country at that time. In the third meeting of the 5th NPC, NPC members blamed the Ministry of Metallurgical Industry for the construction of the BaoSteel project. On January 7 1981, a meeting about the construction of BaoSteel was held in Beijing, where Huang Jinfa, a chief engineer, and Lin Xing, the chief engineer of the BaoSteel project, put forward opinions that were totally different from mainstream thought, despite the potential for political punishment. Lin Xing analyzed the current situation of steel at home and abroad, the construction schedule for the BaoSteel project and the loss suffered from the failure of the project. With the efforts of engineers and the support of top leaders in the Party, the BaoSteel project was shelved. In November, the State Council held a meeting to suspend the project. According to the contract, China compensated over 300,000,000 U.S. dollar to Japanese Mitsubishi for breaking the contract. However, the German company was determined to retain the contract and postponed the construction for six years and the delivery of manufacturing, drawing and technical data of the 2030mm cold rolling project for three years. As compensation, the German company provided China with the drawings of 1700mm cold rolling mill contracted to Siemag AG in 1978. Later on, the drawings were preserved by the first heavy machines plant, which laid the foundation for the cultivation of cold rolling designers.

After 1982, since the national economic situation had improved, the recovery of BaoSteel construction was agreed. In the course of reconstruction, Chinese engineers attached great importance to the ability to introduce technology and accelerate the accumulation of technology. In 1983, the Ministry of Machinery sent a delegation to study in Germany and signed a 50% technology transfer agreement with Siemag (under the condition that each party manufactured 50% of the equipment, and Germany provide China with manufacturing drawings to help China train engineers). At the end of 1983, the BaoSteel project was restored. In 1985, the No. 1 boiler system went into operation, and the 2,030mm cold tandem rolling mill was finished in 1988. The second stage of BaoSteel was comprised of 21 sub-projects, including about 280,000 tons of equipment (about 80,000 tons were introduced from abroad, with the rest made in China). The second stage of the project was mainly based on China, and it adopted the way of "under the charge of foreign company, cooperative design, cooperative manufacture and technology transfer" and introduced single machines or small sets of equipment that could not be made in China. In 1989, 1900mm casting and 2050mm hot rolling went into operation. Other equipment for the No. 2 blast system were put into operation successfully in June 1991, and the equipment localization rate was 61%. At the third stage, the smelting system was designed at home with parts of equipments introduced from abroad; while the steel rolling system was matched abroad with technology at home, and the localization rate was 80%.

While constructing the BaoSteel Project, the team of technicians in BaoSteel was be shaped. The BaoSteel Project was under the direct control of the central Ministry of the Metallurgical Industry, and the general director of BaoSteel construction headquarters Li Ming, the first vice minister of the metallurgical ministry. Huang Jinfa, a specialist in steel rolling, was the vice general director and chief engineer. There, were also three vice chief engineering assistants. Lin Xing, who had been the designer of several large iron and steel bases, was the chief designer of the BaoSteel project. All the general leaders in charge of a project, were site designers sent by design institutions. According to a survey in 1987, the number of senior engineers in BaoSteel accounted for 3.6% of the total number of professional technicians. In addition, in December 1979, BaoSteel headquarters entrusted CAST of Shanghai to employ over 20 engineers from the association to form the advisory committee of BaoSteel led by Li Guohao. The committee discussed many key technical questions including the horizontal displacement of pile foundation, adjustment of BaoSteel construction and diversion works on the Yangtze River. Foreign partners also trained a group of technicians for BaoSteel. For example, according to the J-K contract[123], more than 1,000 technical experts were chosen from over 6,000 technicians to practice with their counterparts in Japan and Germany; besides, at the second stage, a large number of technicians were sent abroad to study: 263 were sent to Germany to study the 2050mm hot continuous rolling mill project; 256 were sent to Japan to study 1,900 slab caster projects which relived BaoSteel's problem of lacking high-level technology. Factories sent a large number of technicians to study in colleges and universities. Over 100 professional courses regarding computer technology and numerically controlled machine tools were held within factories. About one year before the operation, staff had to be strictly tested, assessed, positioned and ranked.

After the first stage was finished, BaoSteel encouraged the government to give some rights to colleges, universities and companies to strengthen its cooperation with those institutions. For example, in 1990, BaoSteel invested 2,000,000 to establish a BaoSteel scholarship to award undergraduates, postgraduates and doctoral students who performed well in their professional studies, social practice or scientific research; the government provided a safe environment and policy support to cooperation between industry,

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[123] In 1980, China signed a software contract about production arrangement and trial with Nippon Steel Corporation. Nippon Steel Corporation regarded the stage of training production staff in capital construction as the J stage, the stage of site instruction and trial as the K stage, thus production training and production guidance was called J-K contract. The contract indicated that Nippon Steel Corporation should provide BaoSteel with production know-how relevant to equipment introduction as well as management modes of demonstration plants like Kimitsu and Oita.

universities and research institutions; as innovative sources and talent bases, colleges and universities provided technological and intellectual support to enterprises; and while enterprises were responsible for developing and making profit, they also had to bear the risk of responsibility for cooperation between industry, universities and research institutions. There was an entrepreneur association comprised of engineers with market knowledge and contractors with scientific understanding. Thus, a win-win situation was achieved through the combination of technology and the market. The technology and equipment level of BaoSteel still lagged behind the international level. The remarkable progress of technology levels relied upon the introduction of technology, and that scientists and engineers of BaoSteel and its research institutions devote themselves to imitating advanced products and the processing technology of steel in Western markets by investing in a significant amount of manpower and material. It also relied upon the study of advanced Western technology, and that well trained Chinese engineers could imitate, research and develop highly sophisticated Western products. It was the main way of developing Chinese technology at the that stage. However, the cost of imitating, researching, developing and substituting for imported goods was high. Therefore, China always emphasized the cultivation of independent innovation, hoping that they could cultivate Chinese engineers in a short time to fill the gap.

Chapter 3 Education and training of engineers

Higher engineering education is centered on cultivating scientific and technical workers who can transform science and technology into productivity. It has two outstanding features: First, it considers science and technology as its main subject basis; second, it aims to cultivate engineers who can transform science and technology into productivity. These two features distinguish higher engineering education from the special contradiction of other higher education - the contradiction between a technological and scientific basis and engineering application objects. It is the development of this contradiction that allows some major characteristics of higher engineering education to take shape.

Early engineering education mainly passed on engineering technologies through the apprenticeship system. After the Industrial Revolution, because of the importance of engineering technology, early-industrialized countries started to establish technical schools to systematically impart engineering knowledge according to different industries. By the mid-19th century, since the further development of engineering technology and the emergence of industries required combining engineering technology with fundamental science, engineering colleges and corresponding engineering departments were founded, but some well-known formal universities did not admit engineering colleges with the view that engineering technology lacked a solid subject basis. Not until the academic nature of engineering technology increased at the end of the 19th century did engineering departments enter into well-known formal universities and specialized higher industry schools come into being. After World War Two, since modern science and technology had rapidly developed and knowledge had increased, how to deal with the relation between basic scientific education and the specificity of technical engineering education itself was a prominent problem in higher engineering education. To solve this problem, different countries had their own educational patterns, thus strengthening the modernization of higher engineering education. From this we can see that higher engineering education is a branch of higher education, belonging to technical education.

In ancient China, there was just the education of Confucian classics instead of a systematic education of scientific and technological knowledge, let alone engineering education. Engineering education in China started after the Opium War when China was faced with a severe crisis. To enhance the power of China and develop industry, reformers of the Qing government proposed creating railways, building ships, opening up the mining industry, training ground forces, readjusting the navy and establishing schools. The Beiyang Western School[124] in Tianjin was established in October 1895, specializing in the subjects of construction, mining, metallurgy and so on, being the first higher education school in China. Later on in 1896, Nanyang Academy,[125] Shanhaiguan Railway Officer School,[126] Qiushi Academy,[127] Tangshan College of Railways and Mines and the Beiyang Academy were established, which were regarded as major institutes cultivating higher engineering technical personnel before 1949 along with Tsinghua University and Zhejiang University.

In the historical course of the modernization of China, technical education was transferred into China from other countries. For example, during the Westernization movement, with the transference of Western shipbuilding, weapon manufacturing technology and technologies of mining and metallurgy, and the introduction of the railway and telegram into China, the late Qing government began to learn from Western countries by establishing scientific and technical schools of shipping, electricity, telegram, mining and railway to train practical personnel. During the period of the Republic of China, the government introduced a large number of military industries including aviation, machine, transportation and textile and civil industries from America and Western Europe, and established a higher engineering education system following the European and American models; for example, Tsinghua University was almost the MIT of China and Tongji University totally adopted the German model. Therefore, the higher engineering education system was not considered and planned as a part of the macro picture of national industrial construction. At that time, higher engineering education in China mainly adopted the European and American education models that had colleges under universities

124 Renamed Northern University in 1912, Tianjin University now.

125 Shanghai, Xi'an Jiaotong University.

126 Southwest Jiaotong University.

127 Zhejiang University.

and departments under colleges without detailed majors in the overall structure. Higher engineering education observed the principle of "general education" and had a wide-ranging curriculum. The teaching process was focused on basic knowledge and technology courses, aiming to help students obtain solid basic theories. By and large, higher engineering education had formed an engineering education pattern centered on undergraduate education.

In 1949 when the CCP took control of the country, engineering education underwent a huge change. First, a new leadership structure came into being - inner-party cadres who issued orders displaced the college-department collective leadership aimed at academic independence. Universities made adjustments and reorganizations. Drawing lessons from the higher engineering education training model of the Soviet Union, a set of higher engineering systems was established by overturning the old ones. With great efforts of adjustments and reforms, engineering training in China had formed a system based on special education. After a retrospective and analysis of the development of Chinese engineers in the last 40 years in Chapter 2, here we will try to find the characteristics of engineering training in China through an analysis of Chinese higher engineering education.

3.1 Single level or Multilevel： the structure of Chinese engineering schools

3.1.1 Undergraduate education: the ever-changing training objectives

An important distinction between the old and new education systems is that the new system's training objective of cultivating various special personnel was clearer. The primary work of the special education model was to make clear the training objective of various majors.

After the "Sovietize Entirely" plan (全盘苏化) of 1952, China made the development and talent training goals of all kinds of universities[128] uniform, in the course

[128] University is used in this paper for the more cumbersome "higher educational institutions". It actually includes comprehensive or multi-disciplinary universities, polytechnic institutes, and specialized engineering, medical and

of adjusting colleges and departments and setting majors. In 1953, following the Soviet example, Chinese colleges cultivated senior science and technology personnel according to different majors. In March 17 1954, the Higher Education Department issued the 'Notice on the Unified Teaching Plane of Four-Year Undergraduates and Two-Year Students in Higher Technical Schools', declaring that the training objective of four-year undergraduate education was to create "engineers", and the training objectives of special courses and postgraduates were to create "senior technicians" and "teachers and scientific researchers in universities" respectively. In 1955, it was found that graduates could not qualified as an "engineer". Thus, in May 19 1955, the Conference on national cultural education determined to change the four-year degree system of higher technical schools into a five-year degree system. It should be remembered that China did not have an equivalent of US diploma degrees. A graduate of an institution of higher education received a diploma, which included the name of the institution, their specialization and number of years completed. It was granted to a graduate of a two-year college as well as to an individual successfully completing a five-year course in a technical institute. Despite the great difference in the length of study and content of curricula, published data seldom differentiates between two, three or five-year graduates.

Around 1957, in the forum organized by the Ministry of Education to revise the teaching program of higher technical schools, a dispute driven by the "double-hundred" guiding principles led to many representatives of universities and colleges having a heated discussion on training objectives, and the titles of undergraduates. Some advocated the title of "engineer", some "bachelor of engineering", and others wanted the two titles to coexist. There were also people advocating "would-be engineer" or "candidate engineer", but these weren't supported.

The reasons for the title of "engineer" were: (1) The title "engineer" could reflect the characteristics of special education, while the title of "bachelor of engineering" implied that basic and professional knowledge were not essential; (2) since the training objective was to become an "engineer", it would have negative effect if it was changed into

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agricultural colleges.

"bachelor of engineering"; (3) undergraduates were qualified to be engineers without practical experience, and the title of "engineer" could urge enterprises and companies to use undergraduates wisely.

The reasons for the title of "bachelor of engineering" were: (1) The title of "bachelor of engineering" meant that someone had reached a certain level in science and technology; (2) though the title of "bachelor of engineering" was an old name (some thought it was easy for people to associate it with idealistic general education), it had new contents - what's more, it was the bachelor of engineering in new China and had an essential difference to the old one; (3) "engineer" was easily confused with "field engineer".[129]

The Chinese dynamicist and applied mathematician Qian Weichang (钱伟长), who disagreed with the title of "engineer", believed that the idea of taking "engineer", as the training objective of higher technical schools was unrealistic. An undergraduate without several years of work experience and knowledge accumulation could be everything but an engineer. It was not possible and was undesirable for universities and colleges to impart all knowledge to students; instead, they must help students obtain certain basic theoretical knowledge and train them to have the ability to acquire new knowledge so as to make them ready to be engineers.[130] However, the dispute had no practical effect, and because of the extension of the political movement, the training objective of "engineer" was seldom mentioned in the following 20 years. Furthermore, as individualism was thought of as "achieving personal fame and a career", "engineers" suffered severe criticism in the realm of ideology. The aim of engineering education was turned into "Ordinary Worker".

The academic degree system issued in 1980 stipulated that the engineering academic degree system include three levels, namely, bachelor, master of engineering and doctor, and that engineering students would gain a graduation certificate from the school, a diploma from the Ministry of Education and the title of Bachelor of Engineering after they finished undergraduate education in fundamental training for engineers. Though a unified

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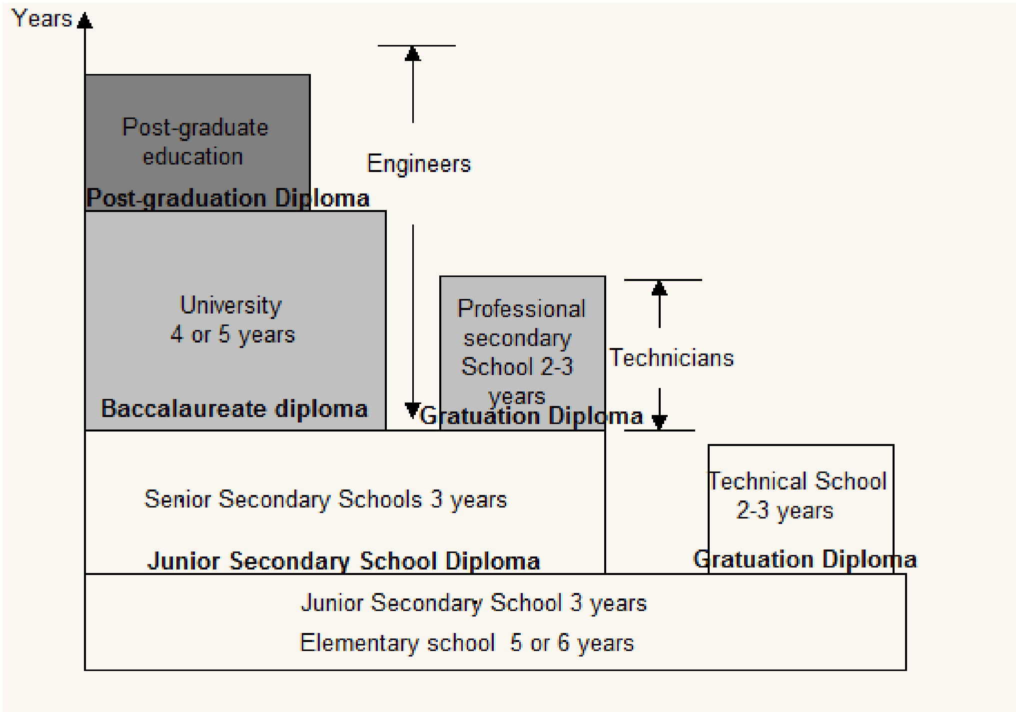
[129] 靳贵珍:中国高等工程教育发展研究，北京：北京理工大学出版社，2012。Jin,Guizhen:Research on the Development of Higher Engineering Education in China. Beijing: Beijing University Press.2012:45.

[130] 钱伟长谈高等工业学校的培养目标问题，新清华，1957年1月23日. An interview of Prof. Qian Weichang: Problems on Cultivation target of Higher engineering Schools, the new Tsinghua University, January 23, 1957.

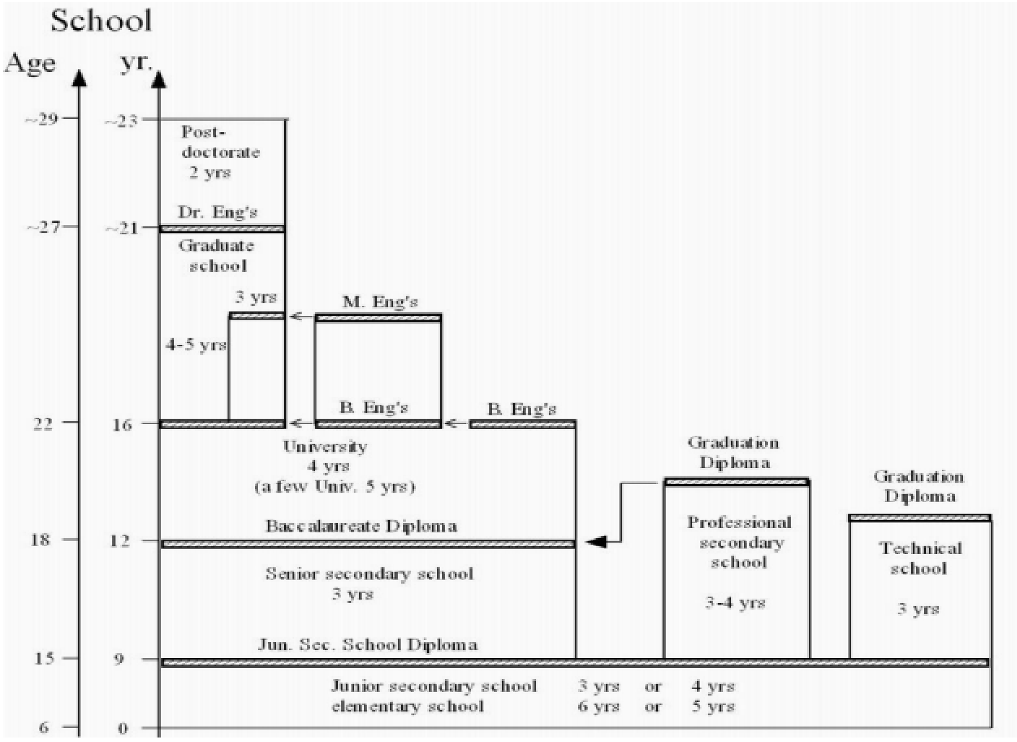
and recognized academic degree system had been established, the training objective of engineers had not been further refined. Furthermore, the question of how to cultivate different kinds of engineers to meet the needs of modern enterprises was not reflected in relevant documents. The uncertainty of engineering training objectives resulted in an ambiguity of engineering education levels. In addition, the fluctuating training objectives in colleges caused professional-secondary[131] and postgraduate education to be improperly located.

Figure 3.1 Structure of engineering education in China before 1980s



[131] see Figure 3.1,Professional-secondary education(高等专科教育) or tertiary education in this paper refers to degrees after Chinese Secondary School Diploma.

Figure 3.2 Structure of engineering education in China after 1980s



Source: H.Winkler:Die Ingenieurausbildung in Deutschland im internationalen Vergleich.

3.1.2 Professional-secondary education: a supplement to undergraduate education

As for engineering Professional-secondary education, though in 1951 it lasted for two years and its training objective was "higher level technician", it had a great flexibility in practical operation. Over a long period of time, professional-secondary education as a supplement to undergraduate education and an emergency measure to meet the need for personnel was quite unstable. In the implementation of the first Five-Year Plan, due to large-scale construction's urgent need for personnel, China established a two-year long special course in engineering colleges to recruit graduates from senior high schools and schools of the same level or students with the same educational background regardless of their age. The enrollment of the professional-secondary schools immediately accounted for 32.2% of the total number of engineering students. The two-year long special course was an intensive cultivating method adopted to meet the needs of the nation-building technical cadres, and its task was to cultivate senior technicians. Compared to undergraduate education, there were fewer majors in special courses (Table 3.1). The establishment of special courses was just a makeshift solution, and its teaching program was comprised of that of undergraduate education. Thus, people believed that it couldn't cultivate professional personnel. After 1955, with the enhancement of work in secondary technical schools, recruitment to special courses was gradually cancelled.

Table 3.1 Comparison between 4-Year Undergraduate and Special Course

Subjects	4-Year Undergraduate Discipline	2-Year "Special Course"
Political theory Courses	Around 400 Hours	Around 200 Hours
Science Courses	Mathematics, Physics, chemistry	Only mathematics
Basic Technology Courses	Around 34% of credit hours	Half credit hours than 4-year undergraduate
Professional Technology Courses	Around 28% of credit hours	Half credit hours than 4-year undergraduate
Russian	3 Years	No require
Dissertation and Design	10-12 weeks	4-5 weeks
Practice	16-28 weeks	14-18 weeks
Summer vacation	6 weeks	4 weeks

Source: 杨东平：通才教育论，沈阳：辽宁教育出版社，1989.5 Yang Dongping: General Education Theory, Shenyang: Liaoning Education Press.1989.5

Under the Great Leap Forward of 1958, higher Professional-secondary education developed rapidly. However, the reorganization started in 1961. From April 21 to mid-May 1962, the Ministry of Education held a nationwide meeting in Beijing during which the country determined to adjust its educational structure and cut down and merge universities on a large scale, particularly, technical schools. Moreover, the remaining higher educational institutions were to be gradually downsized. The meeting put forward a concrete plan: The country would maintain 400 higher educational institutions, including 354 undergraduate schools, accounting for 70.5% of the total number at that time, and 46 professional-secondary schools, making up 13.4% of the total number. In addition, the proportion of professional-secondary students decreased to less than 5% of the total number of higher school students after 1963.[132]

Since the training at professional-secondary schools referred to the training models of undergraduate engineering schools, it did not locate itself properly. Lacking a corresponding diploma, professional-secondary students were awkwardly stuck in the middle of secondary school students and undergraduates. Some schools managed unqualified undergraduates as professional-secondary students in order to motivate undergraduates' enthusiasm for learning. In general, professional-secondary education could not develop completely with its own characteristics. In this way, the task of cultivating senior professional personnel fell on undergraduate education. Therefore, the characteristic of undergraduate education specialization was highlighted and these schools paid more attention to the education of technical skills, being more and more specialized.

On the other hand, the structural variation of secondary school education also resulted in the instability of professional-secondary education recruitment. After 1957, two types of educational systems of the multi-form running school model proposed by Liu Shaoqi were recognized: One was a full-time common university-secondary -elementary school and the other was part-time elementary-secondary school; the former focused on cultivating construction personnel, and the latter on workers and farmers. During the Great Leap Forward, all kinds of secondary vocational schools, vocational high schools and agricultural middle schools sprang up. However, due to the failure of the movement and its unstable policies, reform of the secondary school educational structure did not last, and its theoretical significance overrode its practical meaning. With the development of the "revolution in education" of the Cultural Revolution, the two educational theories were first labeled as the duplication of the capitalist dual system. Instead, a misshapen single secondary educational structure was used, whereby all students were asked to study in general secondary schools. In 1976, the number of general secondary schools reached 58,366,000 and senior high students numbered 148,360,000; meanwhile, the proportion of students from technical secondary schools, technical schools,

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132 张光斗:高等工程教育结构改革研究，重庆：重庆大学出版社，1987.3。Zhang Guangdou: Research on the structure reform of Chinese Higher Engineering Education, Chongqing: Chongqing University Press,1987.3:63.

agricultural schools and vocational schools and students from senior high schools was 1.16%.[133] In line with the cultural requirement of egalitanarianism, the single secondary education structure trained the same type of "new workers". Senior high school education was a prelude to undergraduate education, but the "revolution in education" cut the continuity between them. The unreasonable secondary education structure would inevitably result in difficulties for high school recruitment and unevenness in students' quality.

Table 3.2 Development of Chinese Higher engineering Education[134]

Year	1949	1952	1957	1965	1976	1978	1980
Total Students (Ten thousand)	11.65	19.11	44.12	67.44	56.47	85.63	114.37
Undergraduate students	9.39	13.13	39.33	64.4		45.85	86.19
Secondary school students	2.26	5.98	4.79	3.04	56.47*	39.78	28.18
Proportion of secondary school students	19.4	31.3	10.8	4.5	100	46.5	24.5

*The diploma for graduates during Culture Revelation Period equally to Professional-secondary school graduates.

Although the engineering academic degree system entered into a standardized and orderly stage when, in 1980, the academic degree system determined that the engineering degree consisted of bachelor, master and doctorate degrees, the position of engineering professional-secondary schools was still an issue worthy of discussion.

3.1.3 Postgraduates: the approach to cultivating engineering teachers

Before 1966, China had tried its effort in adjusting engineering education stagesfor two times. In the 1951 education reform period, the State Council issued "the Decision on the reform of school system", stipulating that all colleges, special schools and technical colleges should implement higher education, and all colleges and special schools must

133 于术胜，李兴洲：中国教育三十年（1978-2008）。四川：四川教育出版社，2008。Yu Shusheng & Li Xingzhou: China Education in thirty years (1978-2008). Sichuan: Sichuan Education Press, 2008:75.

134 张光斗:高等工程教育结构改革研究，重庆：重庆大学出版社，1987.3。 Zhang Guangdou: Research on the structure reform of Chinese Higher Engineering Education, Chongqing: Chongqing University Press,1987.3:63.

establish research departments to cultivate postgraduates. In addition, the decision distinguished three levels from the aspect of study and training objectives. Engineering secondary school education lasted for two years with the objective of "training higher level technicians", undergraduate education for five years with the objective of "cultivating engineers", and postgraduate education for 2-3 years with the objective of "cultivating higher school teachers and scientific researchers" - the former was the primary task.

In 1956, the Higher Education Department issued the "Interim Measures of Higher educational institutions Recruiting Candidate Doctors"[135] which determined that students learnt by making study plans under the guide of tutors during their four-year long studies. The first two years were used to study courses, and the last two years were used to write papers. According to a report of the People's Daily on July 19 1956, the number of recruited candidate doctors and postgraduates in that single year was 1,015. Moreover, many well-known professors and academics acted as tutors for candidate doctors and postgraduates. However, the plan was abolished very soon. On March 25 1957, the Higher Education Department gave a notice that the title of "candidate doctor" would be displaced by postgraduate with the term of study cut down to three years. On May 17 of the same year, the Higher Education Department issued another notice which said that it would not hold a thesis defense for "candidate doctors" that year, nor would a corresponding degree be conferred. Thus, the degree of "candidate doctor" was ended.

At that time, the scientific research level of higher educational institutions was not very high; for example, in 1953 the higher education department of the Ministry of Education believed that scientific research was gradually starting, having undertaken the following achievements: (1) Research work and academic activities closely combined with teaching had a preliminary development, including the compiling of textbooks and setting up of labs; (2) scientific research work entrusted to business units began to sprout; (3)

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[135] Russian: Кандидат наук; Chinese:副博士: The first post-graduate scientific degree awarded for original research that constitutes a significant contribution to a scientific field. The degree was first introduced in the USSR on January 13, 1934, by a decision of the Council of People's Commissars of the USSR. This degree was introduced to PRC in the 1950s.

research results of the previous years were cleared up. In practice, some schools regarded the activity of learning Marxist classics and studying textbooks of the Soviet Union as scientific research; some were narrow-minded in understanding the combination between teaching and scientific research, believing that to compile textbooks was to combine with teaching. They put thematic research and the activity of combining with teaching in an opposite relation, and they dared not to conduct thematic research in suitable situations.[136] Technically, scientific research did not start and the task of postgraduate education was only to cultivate high school teachers.

Of course, scientific research work in universities was carried out step by step. In July 1955, the meeting of the second session of the first NPC approved the first-Five-Year Plan of PRC National Economic Development, which stipulated that the country would try to lay a foundation for national scientific research during the first Five-Year Plan. Moreover, in 1956, the country decided to march toward science with scientific research as an important part of higher education. However, the level of postgraduate education was not high. From January 14th to 21st in 1963, the Ministry of Education held a meeting regarding postgraduate work in higher educational institutions in Beijing where they summarized the work experience of cultivating postgraduates in China and centered on the discussion of how to improve the quality of postgraduates. The meeting's minutes pointed out that the country had cultivated over 12,000 postgraduates, including 3,000 engineering postgraduates during the 13 years since the founding of China, and had made some achievements, but most of these postgraduates only studied one or two courses from Soviet experts in order to meet the needs of teaching, lacking a solid foundation and systematic training needed for the ability to conduct scientific research.[137]

After 1963, the country witnessed the establishment and perfection of the training

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136 中央高等教育部综合大学教育司： 全国综合大学一九五三年教学改革的基本情况及对今后工作的意见。高教通讯，1954年 第五期 19 页。Central universities and Education Higher Education Department. The report on basic teaching reform and views on the future work of national comprehensive university 1953. Higher Education Communications,1954,Vol.5:19.

137 刘英杰：中国教育大事典(1949-1990)。杭州：浙江教育出版社， 1993年。Liu,Yingjie：China Education Events (1949-1990), Hangzhou: Zhejiang Education Publishing House.1993:1579.

system of postgraduates in higher educational institutions as well as improvement in the quality of postgraduate education. In 1963, the meeting of higher school postgraduates approved the draft of the "Interim Regulations on Postgraduates in universities" which stipulated that the objective of postgraduates was still to "train people to have the ability to do scientific work and relevant teaching independently", which loaded undergraduate education with the task of cultivating senior professional personnel or part of the mission of educating postgraduates; however, undergraduate education in most schools was unable to finish the task. Furthermore, since education in senior high schools lacked a solid foundation and cut down the schooling year of the Soviet Union from five years to four years, undergraduate education had to be more specialized. In a sense, imperfect postgraduate education had speeded up the specialization of undergraduate education.

Table 3.3 Proportion of Chinese postgraduates[138]

Year	Total Number (Ten thousand)	Engineering Undergraduates (Ten thousand)	Engineering Postgraduates	Postgraduates Proportion of total(%)
1949	11.65	3.03	94	0.3
1952	19.11	6.66	508	0.76
1957	44.12	16.3	628	0.38
1965	67.44	30.53	1808	0.6
1978	85.63	28.76	4011	1.4
1980	114.37	38.35	7200	1.8

3.2 General or special education, a dilemma for Chinese engineering education

So-called 'general education' refers to an educational idea or model which expects to cultivate personnel with certain basic theories, knowledge and skills of natural science, social science and humanity and a fully developed personality. The focus of the value orientation of general education is not on how much specialized knowledge and skills students obtain but on whether their mind and potency have been developed, whether they

[138] 张光斗:高等工程教育结构改革研究，重庆：重庆大学出版社，1987.3 Zhang Guangdou: Research on the structure reform of Chinese Higher Engineering Education, Chongqing: Chongqing University Press,1987.3: 65.

have a sound personality and a relatively reasonable knowledge structure, and whether they could settle down in a changing society. Compared with general education, special education is a kind of educational activity or model which focuses on cultivating personnel able to obtain basic theories, knowledge and skills of a certain subject and the ability to engage in work or study in some field. The focus of the value of special education is not on the integrated development of students including their knowledge, capacity and quality but on how to make them ready for a certain job or industry, have the basic knowledge and skills of the job, and that they can meet the actual demand of social and economic development in various professional areas.

Studies on the training objectives of undergraduate education in new China had never stopped since January 31 1957 when Qian Weichang published "The Training Objective of Engineering Higher educational institutions" in the People's Daily. The several adjustments of engineering higher educational institutions were all centered on this issue.

Since the founding of China, higher engineering education was focused on general education. Mei Yiqi (梅贻琦), the former president of Tsinghua University and the first director of the engineering institute, aired his opinion on the guiding principle for running a school of the engineering institute at Tsinghua University: According to the policy of all departments of the engineering institute, we should lay emphasis on basic knowledge, train students in several aspects and help students to obtain basic skills for various uses. This kind of personnel was needed by Chinese industry.[139] Zhuang Qianding (庄前鼎), professor in machinery, said: "The engineers we need are not only engineering specialists but people who have an understanding in general things and attach importance on basic engineering courses, that's to say, hold the fundamental knowledge. Since engineering cannot be separated from society, engineers should have knowledge of politics, economy, history, geography and sociology. As for engineers in China, we hope they can not only design a plant, but also run an electric motor, thus students must pay attention to other engineering courses even though they major in mechanical engineering, including electrical

[139] 梅贻琦：如何组建工学院的问题。清华学报，1932年379号。Mei Yiqi, Questions about how to organize the engineering institute. School paper of Tsinghua university, No.379,1932..

engineering, engineering material and hydraulics."[140] From this, we know that China implemented general education during the period of the Republic of China out of the needs of Chinese industry: China gave priority to handicraft and light industries, being insufficient in the capacity of mechanized production; what's more, the size of plants was so small that they were not able to employ a large number of engineering technicians. Schools provided many courses, and teaching processes were centered on basic knowledge and technology courses with the purpose of helping students obtain basic theories. Thus, an engineering education pattern based on undergraduate education was formed.

After the CCP gained power, the country witnessed a huge change. In terms of its economy, the country gained the support of the Soviet Union. In order to cultivate technicians as quickly as possible, the work of scaling up enrollment and developing higher education was extremely urgent. The project brought by higher engineering school education in the Soviet Union seemed to be appropriate for China at that time. Special education, totally different from the general education of the Republican period, was carried out in the first half of the 20th century. After the October Revolution, the Soviet Union attached great importance to the cultivation of professional personnel and clearly pointed out in a series of state laws and documents that the ultimate goal of higher education was to train people who could meet the needs of social and economic development. For example, the Higher School Regulations issued in 1921 stipulated that higher educational institutions must cultivate professional personnel for various national economic sectors, and the 1928 "Improvement Measures on Cultivating New Specialists" further emphasized the work of cultivating a group of more professional engineers and technicians with rich experiences. In 1931-1932, higher educational institutions in Soviet set up 900 majors with subtle differences.

Devoted to guerrilla warfare, the CCP lacked the experience of managing higher education, and in addition, since the PRC had only been founded, the central party leaders

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[140] 庄前鼎：好工程师。清华史学研究室，清华史料选集，第二卷，北京：清华大学出版社。1991：278。Zhuang Qianding, Engineer, Research office for Tsinghua University History, Selection History Material of Tsinghua University,Vol.2,Berjing:Tsinghua University Press. 1991:278.

did not understand higher education very well. Because of its ideology, among other things, education in the period of national government could not adapt to the construction of New China. Concerning the teaching contents of higher educational institutions, compiling and adapting British and American textbooks alongside the teaching materials of old China could hardly rid the country of the influence of the bourgeoisie and be suitable for the new system. Compiling a set of textbooks did not contribute to the goals of scientific advancement and systematization.

Concerning teaching methods, the method used in liberated areas was improper to the systematic teaching used in regular higher educational institutions. It was necessary to improve the quality of professional personnel by learning Soviet educational science and the teaching methods of higher educational institutions, which could directly cultivate the various engineers needed to bring in technology from the Soviet Union in the shortest time possible. The construction and implementation of the 156 industrial projects needed a large number of technicians after they came into effect under the assistance of the Soviets. For example, the three big projects, namely, the Anshan Heavy Steel Rolling Mill, the Seamless Steel Tube Mill and the No.7 Blast Furnace, required thousands of technicians during basic construction. It was said that the construction of an automobile factory which could produce 30,000 automobiles each year with the help from the Soviets in design needed about over 600 chief engineers, engineers and technicians and 800 assistants, and the operation of the factory need another 1,600 engineering technicians.[141] After the beginning of large-scale construction, the increase of work in all departments would give rise to shortage of cadres. Taking the department of geology as an example, in 1953 geological examinations increased dramatically. The workload of exploration, geology and topographic surveys was ten times that of 1952 and exploration of slots and tunnels was 24 times.[142] As such, how many cadres would it take to achieve the first Five-Year Plan?

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141 中国社会科学院，中央档案馆：中华人民共和国经济档案资料选，1953-1957，工业卷，中国物价出版社，1998。CASS Central Archives: Economy Selected Archives in People’s Republic of China, 1953-1957, Industry volumes, China Prices Press, 1998:38.

142 宁可主编：中国经济发展史，第五册。北京：中国经济出版社，1999 年。Ning Ke ed.: History of Chinese economic, the fifth book. Beijing: China Economic Publishing House, 1999:2655.

According to the statistics, during the five years, various national economic departments and state organs needed about 1 million professional personnel graduating from higher or secondary schools; meanwhile, departments of central industry, transportation, agriculture and forestry needed about one million skilled workers.[143]

Table 3.4 Types and numbers of industrial technology cadres in the first Five-Year Plan

Category	Number of Enrollment in five years	Graduates in five years	Percentage
Geologic(al) exploration	17500	10000	219.2
Exploitation and management of Mineral	16000	7600	258.8
Dynamic	15500	7500	232.8
Metallurgy	10000	3200	398.4
Machinery manufacturing	54100	19300	395.2
Mechanical and electrical manufacturing	9400	1700	870.2
Chemical Technology	10600	5100	219.3
Paper industry forestry	700	600	127.1
Light industry	4400	3300	138
Surveying mapping meteorology, hydrology	4600	2100	273
Construction and public works	37400	25100	163.5
Transport and Telecommunications	9600	4700	200.5
Others	24800	4700	406.2
Total	214600	94900	266.8

Source: The first Five-Year Plan in People's Republic of China (1953-1957),Selection of important Literature in People's Republic of China.No.6:528.

To achieve these goals, universities and colleges were reorganized and new colleges were established. The establishment of the idea of special education reconstructed the Chinese higher education system, improved the quality of senior professional personnel and met the urgent needs of society in terms of providing professional personnel. The setting of undergraduate programs was based on the needs of nation building. For example, the draft of "Special Provisions in Higher Educational Institutions" in 1954 was based on the national construction department, which included the industrial sector, the

143 中华人民共和国发展国民经济的第一个五年计划（1953-1957），建国以来重要文献选编，第六册，1993年。Chinese Communist Party Literature Research Center ed.: China's first five-year economic development plan (1953-1957), Selection of Important Documents since the founding of the People's Republic of China, the sixth book, the Central Literature Publishing House. 1993 : 525.

construction sector, the transportation sector, the agricultural sector, the forestry sector, the sector of finance and economy, the healthcare sector, the sports sector, the legal department and the education department. Since the PRC developed industry and agriculture simultaneously by giving priority to the development of industry, and industrial construction attracted a lot of investment, developed rapidly, required a higher level of technology and needed more cadres, there were many majors and engineering students. What was most important was that the socialist planned economy of China was identical to that of the Soviet Union, and in addition China had to learn from Soviet higher education in order to cultivate personnel suitable for economic development. Therefore, under the control of the planned economy, it was rational and could meet the needs of economic development at that time to recruit, cultivate and distribute students according to their majors and divide higher educational institutions into majors with clear goals. In the 1960s, however, China did not improve engineering education alongside the development of science and technology in the world but attached great importance to the production process, making majors more professional and teaching contents narrower. Furthermore, productive labor was stressed instead of the teaching of basic systematic theories and technical science, which was another reason for engineers' inability to innovate.

In the 1980s, engineering universities recovered rapidly and teaching programs were improved. In general, however, they had not gotten rid of the influence of the Soviet engineering institutions of the 1950s; meanwhile, they had weakened practice and attached little attention to the link between theory and practice. The defects of hyper-specialized engineering education of this kind were exposed in the wave of reforms. On the one hand, with the economic line changed, enterprises found it more difficult to employ the engineering graduates they wanted since the technical knowledge they learnt in school was too little to solve problems in production; on the other hand, the training mode of engineering universities more and more resembled vocational schools. It was hard to distinguish between the two kinds of school according to their level.

To be more specific, the dilemma of special education and general education in engineering reflected itself in the adjustment of schools, and the setting of majors and the curriculum.

3.2.1 Colleges and departments

The adjustment in 1952 also put emphasis on cultivating construction personnel and teachers, as well as developing special training schools. Higher engineering educational institutions were most aggressive in the adjustment. Universities and colleges were reorganized and new colleges were established. The chief theme of the reform was to emphasize technical training, to reduce basic training and to convert the general system of university education to one of specialized institutes

Prior to the PRC regime, there were 207 institutions of higher learning in China. By the end of 1949, however, this number had decreased to 193, and by 1953, with the reform and readjustment of higher institutions, the number decreased further to 181.[144] It contained 14 comprehensive universities, 33 teachers training colleges, 29 medical and pharmacological colleges, 38 colleges of engineering, 29 colleges of agriculture and forestry, four colleges of political science and law, six colleges of economics and finance, eight colleges of languages, 15 colleges of fine arts, four colleges of physical education, and one special university for the national minorities. 19 engineering schools were involved in the adjustment, and, in addition, there were 11 newly established engineering schools. The adjusted engineering schools could be divided into two types, one being polytechnic universities. Engineering schools with majors under the direct control of the Higher Education Department had changed and standardized themselves through the adjustment, highlighted engineering courses, and helped other engineering schools in teacher training and teaching. The other type were subordinated engineering colleges that cultivated professional personnel for the industrial sectors they belonged to.

In the PRC's scheme for training technical manpower, most of the polytechnic universities offered a great variety of courses in applied science engineering, and technical

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[144] 《中国教育年鉴》编辑部编：中国教育年鉴（1949–1981），北京：中国大百科全书出版社。1984年。"China Education Yearbook" Editorial Office: Chinese Education Yearbook 1949-1981, Beijing: Encyclopedia of China Publishing House. September 1984:964.

fields, while the engineering colleges offered only a limited number of courses in special engineering fields and related applied sciences. Based on original comprehensive universities, the main reform pattern of polytechnic universities was to transfer colleges of science, arts and agriculture to other schools, making engineering colleges independent. They were:

Tsinghua Polytechnic University (Beijing)

Tianjin Polytechnic University (Tianjing)

Harbin Polytechnic University (Harbin,Heilongjiang Province)

Northwestern Technological University (Xian,Shanxi Province)

Jiaotong Polytechnic University (Shanghai)

Jiaotong Polytechnic University (Xian,Shanxi Province)

Tongji Polytechnic University (Shanghai)

Chongqing Polytechnic University (Chengdu Chongqing Province)

Zhejiang Polytechnic University (Hangzhou, Zhejiang Province)

Guangxi Polytechnic University (Nanning, Guangxi Province)

The University of Science and Technology (Beijing)

After 1958 several new polytechnic universities were established. Because these newer centers were constructed with such haste, it is impossible to compare with any validity their academic levels with other institutions established prior to the Big Leap Forward. They were:

Jilin Polytechnic University(Now: Jilin University. Changchun, Jilin Province)

Hefei Polytechnic University (Hefei, Anhui Province)

Shanxi University of Science and Technology (Xian, Shanxi Province)

Jiangxi University of Science and Technology (Nanchang, Jiangxi Province)

Engineering colleges in the 1952 departmental adjustment could show their specialized characteristics more. Engineering colleges cultivated professional personnel for special industries according to their needs and characteristics. At that time, matched with the highly centralized planned economic system, the business department under the State Council established colleges centered on a certain field such as mapping, oil, construction, water conservancy, geology, electricity, steel, agriculture and forestry, communication and hospitals at the service of industrial development in Beijing, Shanghai, Wuhan, Lanzhou, Xi'an, Chengdu, Shenyang, and Nanjing, forming clear industry characteristics in major subject areas and cultivating a large number of senior professional technical personnel for industries.

In 1952, certain central departments established a group of higher educational institutions in Beijing. From their mode of establishment, we can know that all these single-field engineering colleges were based on the combination of relevant departments in comprehensive universities. Since these colleges had only one discipline, they went further in the field, and could thus cultivate professional technical personnel for the industry. Therefore, compared with multi-field polytechnic universities, single-field engineering colleges were more specialized in setting disciplines.

By the end of 1963, the total number of these two types of engineering colleges was approximately 100. In contrast to single-field engineering colleges, which concentrated on one field in engineering or the application of engineering in a single- field of science, the multi-field colleges offered courses covering several fields of engineering-related science and technology. According to an incomplete survey, by the end of 1959 there were at least 59 single-field engineering colleges. These included 16 colleges for construction and hydraulic engineering, three for aeronautical engineering, 11 for chemical and industrial engineering, three for telecommunications, ten for transportation and shipbuilding, and 16 others in the fields of geology, meteorology, oceanography, mining, or metallurgy.[145]

Local engineering schools were another kind of school which had experienced ups and downs in the history of engineering education in China. After the Great Leap by 1958, the country had relaxed its restrictions on the establishment of local schools, thus local engineering schools developing technical strengths emerged at the right moment. However, since the operating conditions were uneven, the expansion of engineering courses was out of order. Some vocational schools upgraded themselves as higher educational institutions,

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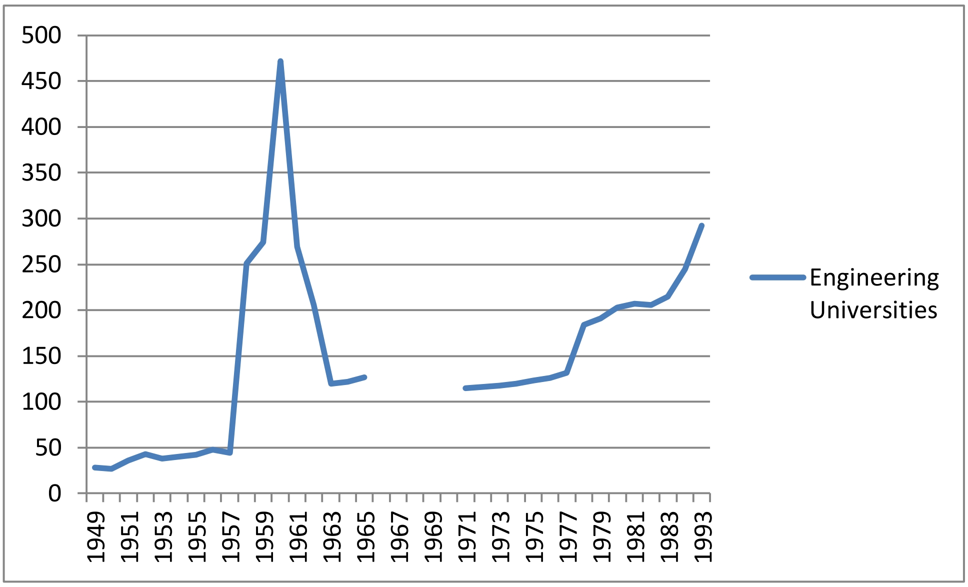
[145] Wang Chi: Mainland China Organizations of Higher Learning in Science and Technology and Their Publications: a Selected Guide, U.S. Government Printing Office, Washington.D.C.20402:Supt.Documents, 1961:17-22.

and some towns and production teams founded vocational schools in certain areas with some schools having only one discipline. In the 1962 adjustment, these engineering courses established through blind expansion were cancelled.

After the third plenary session of the 11th central committee of the Chinese Communist Party in 1978, the country took economic construction as the central task instead of class struggle. In October 1977, the Ministry of Education issued “Opinions on recruitment of higher educational institutions”. The same year after a discussion in the meeting of the central political bureau, the State Council endorsed these “Opinions”. The college entrance examination was officially recovered. In 1977, there were 5,700,000 young people registered for the examination in the whole country, among which universities recruited 273,000. 1978 witnessed the number of young people signing up for the examination increase to 6,150,000, and 402,000 were enrolled. At the same time, a large number of engineering schools were recovered or established. During the two years from 1977 to 1978, there were 58 engineering schools recovered or established, including the Zhengzhou Institute of Light Engineering, Tsitsihar Institute of Light Engineering, Liaoning Architectural Engineering Institute, Guangxi Institute of Light Engineering, Jinzhou Engineering College, Beijing Chemical Engineering College, and Jianghan Petroleum Institute.[146] At the beginning of the 1980s, since the country had delegated some power to higher educational institutions, the autonomy of local higher educational institutions was gradually enhanced. To meet the needs of local industrial construction, the number of local engineering colleges increased. By the end of 1991, there were 286 engineering colleges in the whole country, including 213 universities and special academies, and 73 vocational colleges.

[146] 中华人民共和国教育部计划财务司编：中国教育成就统计资料1949-1983，北京：人民教育出版社。1984。Planning and Finance Division, People’s Republic of China Ministry of Education, ed.:Chinese educational achievement statistics 1949-1983, Beijing: People's Education Press.1984:50.

Figure 3.3 The number of higher engineering schools in China during 1949-1993



The pattern of engineering higher colleges of China was basically shaped, and the previous multi-field polytechnic universities subordinated to the Ministry of Education became universities that represented the higher level of engineering education in China. Subordinated single-field polytechnic universities became schools with their own characteristics in major subject areas. In the late 1980s, however, since special education could not meet the needs of personnel after the reform and opening-up period, some schools of this kind were changed into comprehensive schools to some degree, but engineering courses were still their strong subjects or subjects with their own characteristics. However, some were on the path of reform and adjustment in order to find their characteristics due to problems of finance and teachers.

3.2.2 Disciplines and majors

After the higher education reform of the 1950s, the relationship between disciplines and majors was blurring and the structure of disciplines was weakened; however, majors brought more attention. The development of higher education followed the idea that firstly set majors; secondly put the related majors into a department. Thus, similar or relevant majors made up a certain department. While departments within colleges were cancelled, majors of the same kind (for example, engineering, agriculture, medicine, politics and law, and finance and economics) were combined to constitute an independent university or college. Moreover, the internal structure of universities followed the model of "college-department-teaching and research groups"[147] under the control of the Party committee. In 1952, A. A. Fomin, a Soviet counselor of the Ministry of Education said: "the basic problem of a school is solved if majors were determined. A department came into being by combining majors having same properties. Some departments consisted of 5-6 majors; while some can be comprised of one or two majors."[148] The Higher Education Department pointed out in *Introductions to Adjustment Plan of Majors in Higher Engineering Schools* in 1953 that some schools could not adjust departments properly by combining majors. Instead, they set majors according to teachers and equipments after the adjustment of departments, and some, yielding to the situation, did not have a clear idea about their development directions and the division of work among schools; in addition, some areas (such as south-central, southwest and northwest China) had not adjusted departments or finished adjustments, thus they could only set majors according to the current situation and the problem of repetition and decentralization was severe; furthermore, some similar majors were scattered, for example, there were five higher engineering colleges in Eastern China with majors relevant to communication.[149]

Majors became a main criterion in the work of cultivating engineering personnel. Engineering majors were classified mainly according to product or industry. By 1957, the number of engineering majors in undergraduate schools increased to 183 from 107 in 1952. For example, the department of mechanics in Shanghai Jiaotong University was expanded into the department of machine manufacturing, the department of power machine manufacturing, and department of conveying and hoisting machine manufacturing. The

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[147] This academic structure was based on the Soviet structure of faku'ltey (faculties, or departments) and their subordinate kafedra, which Cice-Rector Cheng Fangwu at Renmin university translated as Jiaoyanshi. The Chinese teaching-research group, like the soviet kafedra, was organized around specific courses or groups of courses within a field, and as its name suggests, was the basic academic group for both teaching and research in a sub-field.

[148] A.A Fomin，李敬永：苏联高等教育的改革一在京津高等学校院系调整座谈会上的讲话。人民教育，1952(9)。A.A Fomin,Li Jingyong：The reform of Higher Education in the Soviet Union- speech at the Conference on the Reorganization of Beijing-Tianjin Higher Education Institutions, Renmin Jiaoyu. 1952 (9): 10-11.

[149] 胡建华：现代中国大学制度的原点。南京：南京师大出版社，2001。Hu Jianhua：Origin of modern Chinese university system .Nanjing: Nanjing Normal University Press, 2001: 195.

department of machine manufacturing consisted of nine majors, namely, mechanical manufacturing, metal cutting machine and tools, metal working and equipments, metallographic heat treatment and workshop appliances, foundry machinery, foundry technology, metal processing, foundry work, and thermal treatment. The department of power machine manufacturing was comprised of automobile manufacture, internal combustion engine manufacturing, turbine making, boiler making and steam power machine manufacturing. The department of conveying and hoisting machine manufacturing was made up of hoisting machine and equipments, steam locomotive making, and car manufacturing. The department of mechanics fell into three departments with 17 majors after the adjustment.[150] Later on, the setting of majors deviated from the original intention of subject-setting. Engineering majors continued to increase, and by 1980, there were 537 engineering majors, among which 152 belonged to light machinery, and 531 to professional sites. For example, to manufacture an engine for a ship, three majors were set for the study of ship turbines, ship internal combustion engines and marine power plants. Furthermore, geological exploration was divided into coal exploration, petroleum exploration, non-metal exploration, and radioactive exploration. The extreme specialized education resulted in engineering students in undergraduate schools study as vocational college students.

In fact, many engineering scholars had raised doubts. For example, some of them believed that the developmental trend of science had become narrower. Electromechanical departments were made up of mechanical departments and electrical departments, and electrical departments were then divided into electric power groups and telecommunication groups, and electric power groups into groups of power supply, electricity generation and electric machinery. Meanwhile, others thought it had no need to be so specialized. They believed that people were not machines and their development was infinite, thus it was not possible to work out norms, nor could students meet the norms. In addition, since production was ever changing, it was hard to set norms, and although they

[150] 郝维谦，龙正中：高等教育史。海南出版社，2000。Hao,Weiqian & Zhengzhong Long: History of higher education. Haikou: Hainan Publishing House.2000:112.

met the norms someday, the next day was different. Moreover, they argued that putting too much emphasis on norms was bound to arrange teaching plans simply according to the needs of enterprises and impart students with concrete but trivial things (in fact, they could not teach students everything), thus not helping students to lay a good foundation for their lives and harming their development. Instead, they proposed setting majors involving many small majors and set additional selective courses, so as to help outstanding students further improve their research abilities in a certain field alongside graduation projects; enterprises should employ applicants according to their ability and give full play to their personnel in the field. Some people, however, thought we should make decisions according to the situation, considering that it was hard to find a perfect solution to employment problems and that some graduates changed their jobs. Thus, since we cannot find a perfect solution, we should broaden the caliber of majors, or otherwise narrow it. Still, there were people who believed we should make decisions according to the conditions of a school. To be more specific, schools with professional teachers could narrow the caliber of majors, or otherwise broaden it.[151]

On the issue of "types of personnel", that is to say, how to make students give special attention to some things according to the division of labor and occupational requirements, some people said, "For undergraduate schools, all engineering students must study scientific technology and engineering technology. Some can put equal emphasis on the two kinds of technology, and some can focus on the one of them; while other students can learn more about applied and basic science, but are also required to learn skills for engineers and engineering technology. As for industrial management majors, we should not only have different standards, but also distinguish the nature of different majors. In addition, students should learn both economic management knowledge and engineering technology."[152] Some scholars pointed out that we should cultivate three kinds of

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[151] 周泽存，徐德淦：试办电气类宽口径专业的几点认识。高等工程教育，1984年01期。Zhou, Zecun & Degan,Xu: Few Comments on Boarder Majors at Electrical Departments. Higher engineering Education. 1984. No.: 1: 49-51.

[152] 张光斗、王冀生主编：中国高等工程教育，北京：清华大学出版社。1995。Zhang Guangdou & Jisheng Wang eds.:China Higher En gineering Education, Beijing: Tsinghua University Press.1995:224.

engineers in undergraduate schools, namely: Engineering and technology-based engineers, engineering and science-based engineers, and technology and science-based engineers. A general view was that undergraduate engineering students could be classified into three types: Technical engineers, management engineers, and technological and scientific engineers. Some argued that in undergraduate schools, the setting of majors was single and these majors covered a narrower area. However, considering the characteristics of engineering disciplines and that the research of applied science was different from research into basic science and that the research of engineering technology was relatively broader than research of basic theory, engineering technicians with a lower degree could also become engineering and technical experts if they worked hard during the long engineering practice. The adjustment of majors started in 1961 broadened the caliber of majors in line with the principle of "the coexistence of the broad and narrow with priority to the broad".[153] In 1963, the State Development Planning Commission and the Ministry of Education revised the Specialty Catalogue for General universities and the Confidential Specialty Catalogue of universities. Unfortunately, however, the revised specialty catalogue had not been carried out effectively.

At the beginning of the 1980s, the industrial community and the educational circle in China held a big discussion on the issue of carrying out general or special education again. The reason was that many enterprises could not recruit students with the relevant knowledge and the demand for certain graduates exceeded supply because of the disjunction between industrial enterprises and higher engineering education. According to statistics from an article published in higher engineering education in 1983, of students majoring in machinery, those with a major in processing and equipment of machinery manufacturing had the best employment situation.[154] Moreover, employers had a preference for these graduates. Senior engineers in the second heavy machinery factory

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[153] 张光斗、王冀生主编：中国高等工程教育，北京：清华大学出版社。1995。Zhang Guangdou & Wang Jisheng eds.: China Higher Engineering Education, Beijing: Tsinghua University Press.1995:224.

[154] 张世煌：从毕业生情况调查看专业设置的调整与改革。高等工程教育研究，1983，S1:106-110。Zhang Shihuan, Research major adjustment and reform, a survey on status of graduates. Higher Engineering Education Research, 1983, S1: 106-110.

thought graduates majoring in mechanics were capable of undertaking the design work, including steel rolling machines and metal forming machinery, and compared with graduates majoring in products they were more familiar with machinery production techniques. That is why graduates with broader engineering knowledge structures were welcomed in machinery factories.

Another reason was that, with the wide use of machine manufacturing, all sectors needed professional personnel of this kind, and the other reason was that since the major was broad and had a stronger adaptability, it had clear main subject (mechanics) and machinery production techniques together with essential knowledge about automation. If they grasped these major subjects and relevant majors, they could undertake work related to technology or equipment in any machine manufacturing sector and automation work in manufacturing processes and equipment. In contrast, some graduates whose majors were aimed at a certain products were gradually left out. In the discussion, some engineering teachers thought that, as for engineering, in order to adapt to the rapid development of science and technology, general education was better than special education, and they illustrated their opinions with the example that although computer graduates had a good knowledge about the major, from a horizontal view, they knew nothing of the mechanical devices controlled by computers and they could not even understand wiring diagrams. Furthermore, they had to receive a long training before their induction. Some teachers argued that it was special education that contributed to undergraduates' inability to achieve and poor innovation ability, thus they advocated for reform. Pan Maoyuan (潘懋源), a domestic educator, put forward a more compromised opinion: General education was more suitable to the educational pattern of America but not China. While special education had its advantages in that the country could make a talent training plan according to the optimized talent structure through manpower forecasting, and give full play to the socialist superiority of the planned cultivation of personnel so as to maximize the efficiency of education. In addition, we should reinforce general education on the basis of special education.[155]

However, the reform was carried out quietly. The Ministry of Education reclassified higher school major subjects in 1983, 1988 and 1992. From the PRC Standards on Discipline Classification and Code implemented in 1993, we can see that standards were highlighted. Main subjects, which were called first-level disciplines, referred to independent major subjects with clear goals and the covered basic majors belonged to the same engineering category (for example, geology, mining industry, metallurgy, and machinery); second-level disciplines referred to majors within first-level majors which were independent and had a broader coverage or had special technical characteristics; while third-level disciplines were majors for special needs and they were made up of a small number.

3.2.3 Curricula

In 1952, to further carry out the special education pattern of the Soviet Union, the teaching reform of colleges and the training system of professional personnel were implemented together with the adjustment of departments. The teaching reform meant that colleges had to change departments into majors and teaching research groups, compile unified teaching plans and programs, and translate the textbooks of the Soviet Union. The curriculum provision reflected itself in teaching plans that were formulated by teaching and research groups, and schools adopted the scholar year system instead of the credit system.

While duplicating the Soviet teaching model for cultivating professional personnel, schools engaged Soviet experts to give directions on the teaching reform and translate and introduce the teaching plan and Soviet textbook; thus, an engineering curriculum system was established according to the Soviet pattern. In 1954, the Higher Education Department approved and issued 199 unified teaching plans and revised 210 teaching

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155 潘懋元主编：中国高等教育百年，广州：广东高等教育出版社。2003。Pan, Maoyuan,ed.: Chinese Higher Education for Centuries, Guangzhou: Guangdong Higher Education Press.2003:370.

programs for basic engineering, technology and parts of professional courses, which were guidance documents for higher engineering colleges to set their own teaching plans. The curriculum mainly included: Public courses such as political theory, foreign language and physical education; basic courses, for example, mathematics and physical chemistry; and professional courses, which were called "three layers" (三层楼). An engineering graduate student required 3800-3900 school hours and 35-36 courses, and his class hours could reach 36 in a single week. Public courses included political theory courses, foreign language courses and physical education. Political theory curricula were comprised of an Introduction to Marxism-Leninism and a History of the Communist Party of China, which together consisted of 190 school hours, and ideological and political education of 160 school hours. Foreign curricula must include at least one foreign language study of 240 school hours. Students in Grade one and Grade two must have two school hours of physical education course each week. An important problem in the structure of the curriculum was properly dealing with the relation between basic courses and professional courses; while this problem had not been solved under the control of special education. The educational system in undergraduate schools was cut down to four years from five, adopting the Soviet model, leading to students having too heavy a study load. All this meant undergraduate students had to focus on the study of professional knowledge and curricula, causing special education to be narrow and the quality of students to be weak.

For example, in 1954 the major of railway engineering had four sub-majors, namely, *railway construction*, *railway lin*es and *business*, *railway houses*, and *water supply and drainage of railways*. Some people even proposed setting two sub-majors under railway construction - *railway location design* and *building*. Specialization was highly valued, for example, in 1954 when examining the teaching plan of the majors of railway engineering and the majors of railway, bridge and tunnel design, the reform decided to cancel unnecessary courses which had little relation to the cultivating objects and courses which was not needed immediately for the current technology, such as thermal and electrical operation and automatic control in power engineering. On the contrary, professional courses should increase their study hours. For example, to strengthen the two specialized courses, water supply and drainage in railway engineering, the courses “railway location design” and “railway construction” should be combined into “railway location design and construction”, and “bridge and tunnel design” should put into “introduction to bridge and tunnel”. In this way, professional courses were greatly reinforced to cultivate engineers with more specialized engineering knowledge and skills for certain job positions.[156]

However, this model of engineering education was doubted somehow. In the forum organized by the Ministry of Education to revise the teaching plans of higher engineering schools in 1957, some believed the key to improving quality was to help students lay a good foundation for further study, obtain basic theories and basic knowledge about professional skills, learn basic knowledge, and understand general ways to solve problems. Li Huiting (李惠亭) from Jiaotong Polytechnic University said we should go against the two deviations - engineering schools putting too much emphasis on physics, mathematics and chemistry would become colleges of science, while putting too much attention on professional courses would become secondary technical schools. Many people believed that the attention paid to basic and professional knowledge should be appropriate and that we shouldn’t emphasize one part at the expense of the other. Li Jihua (李继华), an associate professor from the Architectural Engineering Institute of Chongqing Construction, said basic courses were the basis for cultivating engineers, and they had three properties, namely, service (serve to further study), development (used to solve new problems), adaptation (be variable).[157] Chinese civil engineers and engineering educator Tao Baokai (陶葆楷) commented, “an engineer, no matter their work on design, construction, teaching or scientific research, must have a good knowledge of theories. The more solid the foundation, the better it will be for graduates to solve practical problems. In addition, the teaching of professional courses must be based on the teaching of basic

[156] 张光斗： 高等工程教育结构改革研究，重庆：重庆大学出版社，1987 年。Zhang Guangdou: Research on the Structure Reform of Chinese Higher Engineering Education, Chongqing: Chongqing University Press,1987:35-38.

[157] 张光斗：高等工程教育结构改革研究，重庆：重庆大学出版社，1987 年。Zhang Guangdou: Research on the Structure Reform of Chinese Higher Engineering Education, Chongqing: Chongqing University Press,1987:35-38.

courses. Schools cannot impart all professional knowledge into students in five years, but with a good foundation, they can broaden their knowledge on the basis of what they have obtained."[158] The opposite opinion, however, occupied the dominant position. For example, on the issue of revising the major of mineral geological prospecting, some people said, "graduates of this major must grasp rich geological knowledge. Many basic technological courses are not needed and are impossible to learn. We believed the engineering technical knowledge they received in schools can just help them to know properties of machinery and equipments needed in the process of exploration and selecting appliances properly. Thus, the school hours of basic technological courses could be downsized."[159] Furthermore, regarding cutting down professional courses, he argued, "The reason for some people's idea of cutting down school hours of professional courses was that they believed professional knowledge can be obtained gradually in work. The idea is similar to the opinion of putting off the training of cadres until they are on duty. The thought will make graduates semi-finished products for occupational requirements and mean that they cannot undertake the work very soon, which cannot meet the urgent need of China in professional cadres."[160] Regarding weakening in the teaching of basic theories since 1958, the "Sixty Articles" for universities in 1961 emphasized:

"The teaching of basic courses required learning basic theories of the course first without overemphasizing the combination between the major and the reality. In addition, strengthen the training of basic skills. The teaching of professional courses should help students grasp essential professional knowledge and skills."[161]

The administrative department for education had stressed the importance of basic

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158 陶葆楷：我们是这样研究与修订"工业与民用建筑"专业教学计划的。高等教育，1957(1)。Tao,Baokai: How we study and revision teaching plan of " industrial and civil construction" .Higher Education, 1957 (1): 3.

159 杨起：关于修订矿产地质勘探专业教学计划的几点意见。高等教育，1957(1)。Yang Qi:Few comments on the revision of Geology and Mineral Exploration teaching plan. Higher Education.1957(1): 7.

160 杨起：关于修订矿产地质勘探专业教学计划的几点意见。高等教育，1957(1)。Yang Qi: Few comments on the revision of Geology and Mineral Exploration teaching plan. Higher Education.1957(1): 7.

161 中华人民共和国建国以来高等教育重要文献选编，上下册:上海市高等教育教育局研究室。华东师范大学。1980。Selection of Important Documents for Higher education since the founding of the People's Republic of China Ⅰ,Ⅱ， Shanghai: Shanghai East China Normal University Higher Education Research Bureau: 1980:80.

courses in some notices and provisions, and higher educationists had some wise ideas and thoughts, but why were professional courses overemphasized in higher educational practice? The reason was that undergraduate schools followed the philosophy of specialization. Since society had an urgent need for personnel, required, technical and applied professional knowledge was put in place first; while basic knowledge that did not lead to quick success and instant benefits were ignored. Undoubtedly, people summarized the curriculum provision under the control of special education as "three layers", that's to say, the curriculum could be roughly classified as basic courses, basic technology courses and professional courses, and curriculum provision adopted the logic of "backward structure".[162] Apparently, this kind of curriculum structure met the requirements of special education.

On the other hand, professional courses consisted of basic technology courses, mainly considering the professional development of engineering. The outstanding characteristic of curriculum design was to focus on the design and depth of each course. But there lacked connection between courses. The school hours of basic technology took up a large proportion of whole school hours but the covering scope was narrow, and there was a big difference professional courses within a subject. Therefore, the drawback was that it lacked the horizontal knowledge needed for the comprehensive development of students, including knowledge related to the major, cross-disciplinary knowledge and knowledge of economy, organization and management. The curriculum provision had showed its timeliness in the 1950s to 1960s, and had cultivated ready-made personnel for enterprises rapidly coordinating with the national distribution system.

As time went on, with the development of industry and occupational requirements for engineers, the disadvantages of the curriculum system stood out: Course contents were old; curriculum provision was singular; the caliber of the curriculum was too narrow; and

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[162] Backward structure: It is a principle to set up courses for the specialized education model in China. That is to say, Setting up professional courses is based on professional cultivate aims; meanwhile the technological courses and basic courses are also depended on the cultivate aims. And this training objectives is relatively narrow counterparts expertise, to some extent, it tries to achieve the goal that the engineering students should learn what exactly need when they work in the future.

the curriculum structure lacked flexibility. The biggest problem was that since all curriculum provisions followed the same pattern, the cultivation of engineering personnel was exactly the same and personnel graduating from colleges of the same kind were identical. In the mid-1980s, a discussion on general and special educational curricula was held again in the engineering world and the higher education circle. Many engineering education patterns were introduced from America and the Federal Republic of Germany. Furthermore, the engineering education pattern of the Federal Republic of Germany was imitated as the reform direction of Chinese engineering education. The country gave a certain amount of autonomy to higher educational institutions, and some higher educational institutions started to adjust their teaching plans in a trial subject. With the caliber of engineering majors broadened, curriculum provision was also gradually adjusted. The goal of the adjustment was to reinforce the setting of different courses of the same direction within the subject, to change some professional courses from required courses to optional courses, and to put some professional technology courses into the cultivating stage of postgraduates. These adjustments, however, were limited to certain subjects in certain higher educational institutions instead of being popularized as a wide reform of national higher education.

3.3 Theory and practice

3.3.1 The establishment of practical patterns

An obvious difference between higher engineering education and other higher education was its practicality, which was an indispensible approach to realizing the goal of cultivating senior personnel. After 1952, when China learned from the Soviets and reinforced the construction of teaching procedures, a prominent feature was to stress practical teaching links. In May, 1953, Minister of Education Ma Xulun (马叙伦) issued the "Report on the Higher Education Department: Planning the Department, Reform of universities, Revising the Leadership in Higher Educational Institutions and Enhancing the Production Practice of Students from Higher educational institutions and Secondary

Technical Schools in the Government Administration Council", and gave some suggestions to the problem of production practice. On that day, the Government Administrative Council published the Decisions on Enhancing the Production Practice of Students from Higher educational institutions and Secondary Technical Schools:

"The production practice of universities and secondary technical schools was an important method to help students to link theory with reality and integrate study with application. The Higher Education Department must stipulate interim regulations about production practice of students in higher educational institutions and secondary technical schools by observing the spirit of the Decisions. Firstly, responsible personnel of relevant schools, organs and enterprises were asked to know the significance of students from higher educational institutions and secondary technical schools having production practice for national construction personnel. Secondly, schools must strengthen the organizational work of production practice. The central Higher Education Department and all higher education management organs in greater administrative areas must form central steering committees of production practice and steering committees of production practice of greater administrative areas with representatives of organizations like financial and other business sectors, the communist youth league and the trade union. Relevant schools should have specialized organizations or specialized personnel to organize production practice of students under the leadership of schoolmasters and academic deans. "[163]

In November 1955, the Higher Education Department issued the "Notice on Principles and Methods to Make Sure Sites for Internship and Work out the Allocation Plan of Internship Sites in the Three Years (1956-1958)". In arranging internships, the first thing was to increase the amount of practice time. Engineering students must stay at school for four years, during which they must participate in practice three or four times, including cognition practice, production practice and graduation practice, taking up a total of about 20 weeks, including ten weeks of voluntary work and ten weeks of professional production work. Students took part in practical production work as laborers with the

[163]中央人民政府法制委员会编：中央人民政府法令汇编(1953)。法律出版社，1955。Legislative Committee of the Central People's Government: The Central People’s Government Decree compilation(1953). Law Press, 1955.

purpose of helping students develop labor habits and learn from workers, whilst helping them obtain operating skills, further carrying out the principle of linking theory with reality. Schools and factories worked out an outline for labor and brought it into force. The characteristics of practice during this period of time were:

1) The idea of practical teaching: Learn process knowledge, improve operational ability, and remold their world outlook. Teaching objectives: Learn process knowledge, improve operational ability, and change ideology.

2) Infrastructure of practical teaching: Conventional equipments for thermal and cold working such as casting, forging, welding, lathing, milling, shaving, grinding and griping.

3) Connotation of practical teaching: Learn all techniques reflected in the above-mentioned processing equipments and grasp general technological processes through actual operation.

4) Methods of practical teaching: Adopt stand-alone machines and manual work, and the conventional teaching method of apprenticeship. Since the time for practical teaching lasted for 4-6 or even 6-8 weeks and there were many chances to repeat an operation, students could grasp it better.

5) Objects of practical teaching: Students majoring in mechanical engineering.

6) Management of practical teaching: Teaching contents were limited to conventional mechanical manufacturing since the overall level of practical teaching was low and the courses involved were less, thus the teaching management at this stage was relatively simple by using conventional methods, and the workload was light.

The practical process put more emphasis on practical problems in factories but less on students' knowledge, skills and ideology in conventional engineering practice. The objective of practical teaching still focused on testing theoretical knowledge and grasping experimental and training skills without strict requirements in their sense of duty, ability of expression, innovation ability, and team spirit, thus it was unreasonable. In addition, since practical processes lacked supervision and evaluation of practical teaching became a mere formality, the strength and effect it had in developing practical ability was not enough.

3.3.2 The deviation from practical patterns

During the Cultural Revolution, schools deviated from practical work since the authorities tried to eliminate the division between intellectuals and workers or farmers through physical labor. The authorities ran schools in an open-door way, connected factories with schools, and overemphasized unprofessional physical labor, changing professional production practice into productive labor. This kind of action wasted a lot of time in productive labor and ignored the study of cultural knowledge and professional skill training instead of bringing the advantages of accumulating professional practical experience to students.

In 1978, the Ministry of Education published its opinions on scientific teaching work and engineering in universities, made rules on problems relevant to teaching plans, determined that engineering undergraduate education should generally last for four years, maintained the principle of focusing on professional study which should make up 146 weeks (with other courses and activities taking 36 weeks), and stipulated that theoretical teaching and teaching experiments should account for at least 80% (the proportion between them was 1:1.5) and the class time of basic courses 70-75%, and that courses and contents must be fewer but better.

According to the draft of the Ministry of Education's provisions on higher engineering schools revising the teaching programs of undergraduate schools, the internships and practical training of the four-year long engineering undergraduate education must include military training, metalworking practice, social practice, voluntary work, curriculum design or experience of several courses, cognitive practice, production practice and a graduation project or thesis which accounted for 10-14 weeks (14-18 weeks for schools with five-year long education). In addition, voluntary work made up a week. All internships should be connected with theoretical teaching and professional work according to the internship plan. Industrial work should be combined with the major and be arranged with practical processes such as internships.

However, like foreign higher engineering education, the practical training in engineering education had been established since the country introduced Western models despite lacking an industrial base. The drawbacks of running schools like this were reflected in the following two aspects: First, it lacked the cultural tradition of being closely connected with engineering practice and of being interested in engineering technology; second, it had not formed a close connection of mutual development and promotion with industrial innovation. In the higher education world of engineering, the characteristics specific to engineering education were not obvious. Under the current educational management system, universities were weak in opening to the market and the connection between engineering education and industrial circles was loose. The decision to run a school and determine their objectives was not made by enterprises and the market but designed by educationists and scientists, without the participation of engineers.

At the same time, following the profound changes to economic structures and company conditions, the previous practical teaching, which mainly relied on coordination between factories and schools, fell out of fashion. In addition, the practical side of engineering education in undergraduate schools was dramatically weakened; equipment in experimental and training bases were old; plant practice was hard to carry out; engineering comprehensive design was ignored; teachers lacked practical engineering experience; and students had poor ability in practice and innovation. Now, many engineering majors in higher educational engineering institutions stuck to the teaching mode of pure science; furthermore, engineering practice was widely displaced by computer simulation.[164] Kong Chuiqian (孔垂谦), an associate professor from Nanjing University of Aeronautics and Astronautics, believed that the pattern of engineering education in Chinese undergraduate schools showed the trend of "de-engineering"; theoretical teaching was centralized; engineering practice was marginalized gradually; and engineering practice was formalized until it finally became an appendage of engineering education.

We can say that the idea of Chinese engineering education was not clear; its strength and effect in cultivating students' practical abilities was not enough. Some said that

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[164] 姜嘉乐：工程教育永远要面向工程实践—万钢校长访谈录。高等工程教育研究，2006（4）。 Jiang Jiale: Always facing engineering education engineering practice - President Prof. Wan Gang Interview . Research in Higher engineering Education,2006(4):1.

scientists explained the world while engineers changed it. It seems that engineering students trained in China preferred to explain the world, and that the aura of engineers did not shine as bright as that of scientists.

Table 3.5 Proportion of Practice teaching in Higher engineering education[165]

Year		1952	1957	1963	1979	1985
Length of study		4	5	5	4	4
Units（weeks/credits）		195	256	256	202	202
Theory education term		114	144	144	133	112
Practice education (weeks)	Military Training					5
	Volunteer labor		5	4	2	1
	Computer Training					1
	Survey and Map					2
	Design	4	3	13	3	7
	School practice	3	15	12	6	4
	Productive practice	14	16	13	5	5
	Cognition Practice					2
	Graduation Design	10	21	16	10	14
	Total	31	60	58	26	41
Practice education weeks proportion of total(%)		15.9	23.4	22.7	12.9	20.3

3.4 Examples: Tsinghua University and Beijing Institute of Electric Power

This chapter has dealt with patterns of engineering education from aspects of its types of universities, cultivation aims and curriculum. In this part, we want to take two particular types of universities as example to show how the engineering education was formed in universities. These two types of engineering universities are Tsinghua University and Beijing Institute of Electric Power. Tsinghua is one of the oldest engineering schools in Chinese history, it shows the tradition and changes of engineering education between

165 This table is based on the "Higher Engineering Education for the 21st Century teaching contents and curriculum reform plan" work of the Steering Group, ed. Challenge exploration and practice: Higher Engineering Education for the 21st Century teaching content and curriculum reform research (Episode 1). Beijing: Higher Education Press, 1997:147.

KMT and PRC government. It is also the typical engineering insitute, which has been through the educational reform of the 1950s as a polytechnic university. The foundation and development of Beijing Institute of Electric Power is a particular case which represent local engineering secondary schools under the special social and political background.

3.4.1 Polytechnic University of Tsinghua University

3.4.1.1 The establishment of Polytechnic University of Tsinghua University

In 1925, Tsinghua University officially set up undergraduate departments. In the 17 departments established in 1926, an engineering department was one of them, including three courses, namely, mechanical engineering, electric engineering and civil engineering. Due to economic restrictions, the authorities of Tsinghua University put the emphasis of running a school on traditional, strong courses. Therefore, in practical operation, the engineering department shrank rapidly and was renamed as practical engineering with the purpose of training a kind of personnel who had basic knowledge about construction, machinery and electric machinery, instead of learning a single course. The practice seemed to meet the situation, but it was very soon proven to be impractical for it was impossible for anyone to know about all techniques in four years. Thus, in the next semester, the objective of practical engineering was further compacted and the subject was renamed 'municipal labor administration'.

In the winter of that year, faced with the problem of having to increase equipment, the board of directors of Tsinghua University were forced to cancel engineering courses regardless of the objections of teachers and students. Before long, with the dissolution of the board of directors of Tsinghua University and the fact that the school was affiliated to the Ministry of Education as a national university, the authority of Tsinghua University recovered the Department of Engineering while establishing a College of Arts, College of Science, and College of Law due to the development of situation and the pressure from all parties. One year later, the engineering department was called the 'department of civil engineering' again.

Although the engineering for civil engineering were single departments, 30%-40% of enrolled students resisted in it, causing a rapid increase in engineering students.[166] The expansion forced the authority of the school to enlarge the organizational system of the department, thus putting the issue on the agenda. As the council of Tsinghua University determined to set up an engineering college, it immediately applied to the Ministry of Education for approval: Since our school took efforts to cultivate engineering personnel, we planned to establish a department of mechanical engineering and department of law, and we also determined to change the civil engineering department into an engineering college.[167] Meanwhile, Tsinghua University also filed an application to set a department of law in the College of Law, but the Ministry of Education indicated that since there was an urgent need for engineering personnel, the school should try to expand the engineering college with all their efforts and put off the recruitment of students majoring in law, considering the current situation of the country.[168]

From this, we can know that the establishment of the engineering college at Tsinghua University was driven by the urgent needs of society; furthermore, the efforts of teachers and students in Tsinghua University and the governmental policy of "promoting engineering and restricting arts and law" played an important role at a certain period of time and environment. In the autumn of 1932, the Engineering College of Tsinghua University started to recruit students. Regarding the idea and policies of the running of the Engineering College of Tsinghua University, Mei Yiqi the president of Tsinghua University at that time said, "The policy of all departments in Engineering College was to stress basic knowledge. In addition, trainings could not be too narrow but help students obtain basic skills."[169] The real reasons were identical to (the Minister of Education in the KMT

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[166] 方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。Fang,Huijian & Sijing Zhang eds. Tsinghua University. Beijing:Tsinghua University Press,2001:62.

[167] 方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。Fang,Huijian & Sijing Zhang eds. Tsinghua University. Beijing:Tsinghua University Press,2001:62.

[168] 方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。Fang,Huijian & Sijing Zhang eds. Tsinghua University. Beijing:Tsinghua University Press,2001:62.

[169] 梅贻琦：关于组建工学院的问题，国立清华大学校刊，1932年，第379号。Mei, Yiqi: Issues on form the college of engineering. Tsinghua University Journal.1932,No.:379.

government) Gu Yuxiu's (顾毓秀) opinion: Professional work including agriculture and manufacturing was very detailed, thus school education could not teach students all these things, and the teaching of these things were not necessarily beneficial.[170] Zhuang Qianding also pointed out: "The engineers we need were not only engineering specialists but people who have an understanding in general things. Attach importance to basic engineering courses and hold fundamental knowledge. As for engineers in China, we hope they know something about general engineering."[171] He told students from department of mechanics, "Engineering education in undergraduate schools just lays a foundation for your engineering career. Based on that, you need to seek sound experience."[172] From this, we can know that it was a characteristic of the philosophy observed by the Engineering College of Tsinghua University in running a school in the early days to emphasize basic education as the basis of the theory of general education. This characteristic not only showed the tradition of Tsinghua University in running a school, but also reflected the need for social development at that time.

At the foundation of the Engineering College of Tsinghua University, it was made up of three departments, namely, the department of civil engineering (including railway and road engineering groups, and water and sanitation engineering groups), the department of mechanical engineering (including motive power engineering groups, mechanical manufacturing engineering groups, and aircraft engineering groups), and the department of electrical engineering (including electricity groups and telecommunication groups). The courses of the Engineering College were arranged according to the following principles: Courses in Grade 1 included Natural Science, Chinese Language, Foreign Language, and Introduction to Economics; most courses in Grade 2 were basic engineering training, for example, measurement, statics, dynamics, and mechanics of materials; students in Grade 3

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[170] 顾毓秀：专门人才的培养，独立评论，76期，1933。Gu Yuxiu: Training of specialized personnel, independent reviews, 76, 1933.

[171] 庄前鼎：健全的工程师，清华大学史料选编，北京：清华大学出版社，1991。Zhuang Qianding: Qualified Engineers, Selection historical materials of Tsinghua Universities. Beijing: Tsinghua Pubilshing House,1991:278.

[172] 庄前鼎：健全的工程师，清华大学史料选编。北京：清华大学出版社，1991。Zhuang Qianding: Qualified Engineers, Selection historical materials of Tsinghua Universities. Beijing: Tsinghua Pubilshing House,1991:278.

started to learn general professional subjects such as water supply engineering as well as railway and road engineering for the department of civil engineering, principles of mechanical designing and combustion motors for the department of mechanics, principles of electric and electronic engineering and studies of the telegraph and telephone for the department of electrical engineering; while in Grade 4, students were grouped according to majors for more specialized education in aprofessional engineering knowledge area.

3.4.1.2 Departmental adjustment with the Soviet pattern as the model

Societies often tried to reorganize education during national crisis and great events.[173] With the change of ideology in January 1949 after the liberation of Peking, the new committee of culture proposed that Peking University and Tsinghua University needed to be adjusted due to the unbalance of repetitive development in higher educational institutions in Peking. On March 14 1949, the committee of culture and education held a discussion about education in colleges, and the problems of curriculum reform and departmental adjustment in national colleges in Peking; the existence and improvement of private universities were the main issues in the discussion. After the meeting, the central government believed that there were a small number of professors in Tsinghua University who advocated for adjustment due to their deep sectarianism, thus, it advised schools like Tsinghua University and Peking University to employ a group of advanced professors in social sciences and literature so as to have the upper hand in the future merger.[174] On May 27 1950, the Ministry of Education held a discussion about problems in higher education at Tsinghua University in order to make preparations for the meeting of higher education and to seek opinions on the drafting of a law of higher education. The discussion mainly involved professors from Tsinghua University, Peking University and Yenching University, and Zhou Zhongqi (周钟歧) and Yang Minhua (杨民华), both of whom were heads of

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[173] Andreas M. Kazamias, Byron G. Massialas: Tradition and Chance in Education: A comparative study. Prentice-Hall, 1965:169.

[174] 中央关于北平各大学的几个方针问题的指示。1949年3月17日。中共中央文件选集十八，1949。Instructions on several policy issues of Peking universities by central commitee. March 17, 1949. CPC file anthology eighteen ,1949:1-9.

the technical education department at the Ministry of Education. The discussion was about the following issues: the nature and tasks of universities; general education and special education; how to understand the relationship between theory and practice; curriculum reform and departmental adjustment; and the training of teachers. In the discussion, the developmental direction of the specialization of college education proposed by the Ministry of Education failed to get the agreement of professors who said that the nature of universities was to be all-sided, upward and creative, and that universities must be comprehensive, engineering colleges should not be separated from colleges of science and law, and people trained in colleges should be creative personnel on the basis of general education instead of practical personnel with a narrow range of interests. Obviously, the scheme deviated from the original intention of the government. Furthermore, the slow progress of departmental adjustment in the previous two years proved the necessity of the ideological reform of intellectuals in the view of the top leaders.

With the development of "Three-anti and Five-anti Campaigns", and the reform of intellectuals, the resistance against departmental adjustment decreased and opinions on adjustment and reform tended to be consistent. In November 1951, the Ministry of Education held a national conference of deans from engineering colleges to discuss the problem of adjustment in engineering colleges. In addition, in the preparatory meeting, the Ministry of Education formulated a preliminary scheme of adjustment in engineering colleges that proposed changing Tsinghua University into a multi-field polytechnic university with the same name instead of copying the Soviet pattern. At the end of November 1951, however, the Ministry of Education changed its idea on the adjustment of the College of Science of Tsinghua University. Ma Xulun submitted to the 113th conference of the Government Administration Council the "Report on the Adjustment Scheme of Engineering Schools" which proposed incorporating the College of Arts, College of Law and College of Science of Tsinghua University and departments of arts and law of Yenching University into Peking University. The report stated that in 1952, educator Zhang Zonglin (张宗麟) published the "Start of Engineering Education Reform in Higher educational institutions in the first stage of People's Education" where the relation between the college of engineering and college of science was discussed. In addition, he pointed out that some independent engineering colleges did not establish colleges of science and employed science teachers to teach science courses, thus the problem was simple. While most engineering colleges coexisted with colleges of science and the number of the two kinds of colleges had a huge difference, all these had given rise to mutual discrimination. Furthermore, the tasks of the two kinds of colleges were not clear, and science teachers were unsatisfied that science colleges were in the service of engineering colleges instead of focusing on managing for themselves. Thus the two schools were unbalanced in curriculum; for example, colleges of science within engineering colleges also set departments of biology, pharmacy, psychology, geography and astronomy.[175]

Under the influence of many factors, the Ministry of Education finally determined to transfer the College of Science of Tsinghua University into Peking University, and on April 16 1952, it published the "Adjustment Plan of Engineering Colleges". In addition, in May of the same year, it issued the "Adjustment Plan for Departments". Henceforth, departmental adjustments, which had a great influence on engineering education in Chinese higher educational institutions, entered into an implementation phase, and Chinese universities systematically turned to the Soviet model.

On June 25 1952, the Ministry of Education established the bureau of departmental adjustment in universities in Beijing and Tianjin. Moreover, Tsinghua University and Peking University also established their own offices of departmental adjustment with Liu Xianzhou as the office director and Qian Weichang, Chen Shibi and He Dongchang as vice directors of Tsinghua University to organize and execute adjustment work. Departmental adjustment of the colleges of science and engineering in Tsinghua University included the following aspects:1. Adjustment of teachers

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175 方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。Fang,Huijian & Sijing Zhang eds.,Tsinghua University. Beijing: Tsinghua University Press,2001:68.

According to the departmental adjustment plan formulated by the Ministry of Education, a huge number of teachers in the College of Engineering of Tsinghua University were, on the one hand, transferred with the establishment of various engineering schools in Beijing; for example, the department of aviation was transferred to the Beijing Aeronautical and Astronomical Institute, and the department of mining was divided into a coal mining group and a metal mining group which were transferred to the Beijing Institute of Mining and Beijing University of Iron and Steel Technology respectively. In 1953, the School of Petroleum Engineering, on the basis of the department of chemical engineering in Tsinghua University, was transferred to the Beijing Institute of Petroleum. On the other hand, teachers in departments of chemical engineering at Peking University and Yenching University were not moved to Tsinghua University. According to the work report of the Tsinghua University preparatory committee of second stage departmental adjustment in universities in Beijing and Tianjin, the central government shifted 45 engineering teachers from the three schools, including 22 students from Tsinghua University, 13 from Peking University and 10 from Yenching University. These teachers were transferred to Shanxi University, Harbin Institute of Technology, Military Engineering College, Tangshan Railway College affiliated to the Ministry of Railways, Tianjin University, and the Chinese Academy of Sciences respectively, while most teachers from the department of chemical engineering of Yenching University were transferred to Tianjin University. Therefore, the number of teachers in some engineering departments of Tsinghua University decreased instead of increased. For example, the department of mechanical engineering had six professors who specialized in mechanical parts, but five of them were transferred.

In March 1953, the president of Tsinghua Jiang Nanxiang (蒋南翔) pointed out the shortage of teachers in Tsinghua University in the reports submitted to Party leaders Xi Zhongxun(习仲勋), Yang Xiufeng (杨秀峰), the propaganda department of the Central Committee of CCP, and the Beijing Municipal Committee. To solve the teacher problem, universities employed experts to give lessons to teachers and students, including 63 Soviet experts, four German experts and one Czech expert. These experts also helped to found 37 labs, set 103 engineering courses, compile teaching materials, assist new teachers, and provide guidance in scientific research. Furthermore, universities invited experts and engineers from the Academy of Sciences, industrial enterprises and other relevant units, including Hu Hanquan (胡汉泉), the chief engineer Wu Hongshi (吴鸿适) and deputy chief engineer in the China Electronics Technology No.12 Institute, and semiconductor engineer Wang Shouwu (王守武) in the institute of Applied Physics CAS, and so on. Most important were a group of young teachers who stayed after graduation before and after the 1950s, most of them members of the Communist Party. After 1956, some professors who had studied abroad were labeled as "rightists" and were excluded from first-line teaching jobs and scientific research. A group of young teachers who grew up under the new ideology in the early years following the founding of the country, however, had become major academic figures with little engineering practice but great efforts on theoretical teaching. They passed this insufficient practical ability onto the next generation. The Soviet quote that only engineers could cultivate engineers gradually became an empty phrase after the experts had left.[176]

Furthermore, in 1952, after the departmental adjustment, teachers were classified into 36 teaching and research groups that belonged to the three categories, namely, public theory courses, public technical courses and professional courses. In general, the groups were in line with the professional emphasis of engineers. For example, since the department of water conservation included the majors of hydraulic structure engineering and of water use, there were corresponding groups. Major professional teaching and research groups were responsible for the final stage of cultivating engineers and played a leading role in departments; they needed not only take charge of the teaching of professional curricula, but also to provide guidance to students on internships and graduation projects. Teaching and research groups of public theory courses and public technical courses should serve to all teaching links, and the examples must be in the range of the major. Teaching and research groups were the main way of organizing teachers in

[176] 傅水根：我国高等工程实践教育的历史回顾与展望，实验技术与管理，第 28 卷第二期，2011 年 2 月。Fu, Shuigen, Historically looking back and developing trend on the higher engineering practice education. Experimental Technology and Management.Vol.28,No.2,Feb.2011:1-4.

Soviet universities, with a director who was a professor or deputy professor managing teaching work directly. The selection of directors for teaching and research groups in Soviet universities was very stringent: Candidates recommended by principals had to win the approval of the Higher Education Department. Therefore, the status of directors was very high. As opposed to the organization of teaching and research groups in Soviet universities, groups in Tsinghua University, besides a director, had a teaching secretary to assist the work of the director in organization and administrative work. The position of teaching secretary was generally taken by Party assistants or League members. In the actual work of the later stages, teaching secretaries who were also Party or League members started to intervene in teaching and research groups and departments in teaching and other work, creating a phenomenon of "dictatorship of secretaries". In 1956 during the period of "airing views", some teachers considered it as a phenomenon that administrative power overrode academic power. This was also a big difference between Chinese educational reform and the Soviet educational system.

2. The setting of majors

The setting of majors was an important part of the reform of Chinese higher education in the early 1950s. According to the need of industrial sectors and the setting mode of Soviet multi-field polytechnic universities, Tsinghua University set 22 majors in the departmental adjustment of 1952, apart from 15 special courses used to meet the urgent need of industrial construction in technical personnel that was beyond Soviet universities. After 1955, the Higher Education Department gradually cancelled special courses in universities. The pattern of setting majors in Soviet universities had a great influence on the setting of majors in Tsinghua University, thus the setting of some majors was influenced by the Soviets, without considering the actual requirements of industrial development in China. For example, the department of civil engineering proposed setting the major of edaphology, according to the requirements of industrial circles, to cultivate engineers in the foundation of houses and hydraulic structures, and with professors including Yang Shide (杨式德), Chen Xiaozhong (陈效忠) and so on, the proposal could without doubts have been achieved. However, since the Soviets did not have the major, the proposal was objected to. Similarly, the major of watershed planning and watercourse management and the major of town planning suffered the same fate. To be more specific, the major of town planning aimed to cultivate personnel who understood urban planning, and building design had teachers including Liang Sicheng (梁思成), Wu Liangyong (吴良镛) and so on who were all famous architects; besides, the country had some corresponding experience. However, since the Soviets had no such major and corresponding teaching plans, the proposal was also refused. In the setting of some majors, however, the suggestions of Soviet experts were not decisive; for example, the decision of Tsinghua University to set a major in radio engineering was objected to several times by the Soviet experts in the Ministry of Education as well as the later consultant of the principal of Tsinghua University, but with the efforts of people including Liu Xianzhou (刘仙洲) and Qian Weichang (钱伟长), a department of radio engineering was established. Another prominent problem was that after the adjustment, Tsinghua University did not have humanities courses except for Marxist theory, ideology and morality, and foreign language.

3. Introduction of the Soviet teaching system

With the establishment of various teaching organizations including teaching and research groups and majors, Tsinghua University started to gradually bring in various teaching systems from the Soviet Union, such as teaching plans, teaching programs, textbooks and exercise classes, and graduation projects. Most of these systems were established with the assistance of Soviet experts. In the new teaching plans and teaching programs, learning from the Soviets, the major characteristic was specialized teaching according to the major. Students from different majors were different in content and number when receiving basic theoretical courses. Teaching contents were usually combined with actual needs of the major. Taking the change of course contents in the department of civil engineering as an example, physics classes just included the teaching of properties of solids and fluids with contents in optics cut, and the contents of selection, installation and operation of electric motors in construction sites as well as exterior design added to courses of electro-technology.

Class hours of the same course were also adjusted according to different majors in the new teaching plans. Class hours of basic theoretical courses and basic technical courses of different majors were individual, which was different from the American educational system whereby basic courses like physics, chemistry and mathematics were open to all students in Grade 1. It is noteworthy that in 1957, some people realized the drawbacks of excessive professionalization. For example, when the department of civil engineering of Tsinghua University revised the teaching plan of the industrial and civil construction major, since people agreed that an engineer should have a wide professional knowledge (although some proposed dividing the department into construction and engineering in Grade 4 and Grade 5), the department was not specialized but adopted the method of selecting courses to let people have a deeper understanding of certain elements in the last three semesters. Only when they had a good theoretical foundation, wider-range professional knowledge, and a deeper understanding of an aspect could they have the ability to improve themselves and solve actual problems independently after graduation.[177]

After a development of less than 10 years, Tsinghua University had witnessed a huge change in educational system, teaching contents and teachers. The departmental adjustment marked the thorough transmission from the European and American pattern of education to the Soviet pattern, which was meaningful from the perspective of the emerging industrialization of China. In 1952, the number of engineering students was three times the highest record before 1949. The developing engineering colleges had provided a large number of personnel for the industrial and national defense construction of the new China, and Tsinghua University gradually become the cradle of "red engineers" for the Communist Party.

3.4.1.3 The implementation of informal teaching systems

After 1956, methods like "flourishing everywhere", "renovating majors" and "broadening majors" had increased the number of new technology majors. Furthermore,

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[177] 陈大白主编：北京高等教育文献资料选编（1949-1976），北京：首都师范大学出版社。2002. Chen Dabai: Selected literature of Beijing Higher education (1949-1976), Beijing: Capital Normal University Press. 2002.

schools took great pains to develop cutting-edge majors; for example, after 1956, Tsinghua University established new majors in engineering physics, metallographic heat treatment, remote machinery and automatic equipment.

In 1958, trying to break through the limitations of Soviet educational experiences and explore a socialist higher education system which was suitable for the actual conditions of China, an educational reform was carried out with a work-study program and the combination of education and productive labor as major points. At that time, taking the implementation of "combining education with productive labor" as the sally port, the reform expanded to teaching plans, teaching content, teaching methods, and so on. Meanwhile, it also promoted the development of school-run factories and the construction of campus bases (named Sanlian bases) featuring a combination of teaching, scientific research and production. The Ministry of Education in China cancelled the unified teaching plans, delegated power to the lower levels, changed teaching plans into guidance documents for teaching, and incorporated productive labor into teaching plans.

Schools were to take efforts to run factories so as to combine education with productive labor. In the teaching plan for five-year studies, education about productive labor and practice lasted for about 55 weeks, doubling the number of the early years. With the increase of time for productive labor, schooling time for basic courses, basic technical courses and professional courses were reduced. Moreover, there were some achievements in graduation projects, and some students took part in the research and design of key national projects, for example, the graduation project of the preliminary design of Miyun Reservoir, made by about 200 students, including students from the department of water conservancy and students majoring in electricity generation at Tsinghua University under the guidance of teachers. The participation of engineering practice linked theory with practice which had not only completed the national construction and production tasks, but also had cultivated students, allowed teachers and students obtain engineering experience, and improved the ability of engineering practice.

The results achieved through this method were rapidly affirmed, thus the scope of production practice was extended to lower grade students from senior students and young teachers (see Table 3.6). 1961 and 1962 witnessed the biggest influence of the action. Although the length of schooling in the two years was increased by half a year, students' time for theoretical study was less than that in former years and the time for production practice was doubled. This could affirm the hysteresis quality of education: The effect of things happened two years ago reflected itself two or three years later.

Table 3.6 Time schedule and teaching programs of Machinery manufacturing, 1957-1966

Grade Term	1957 (5-Year)	1958 (5-Year)	1959 (5-Year)	1960 (5-Year)	1961 (5.5-Year)	1962 (5.5-Year)	1963 (6-Year)	1964 (6-Year)	1965 (6-Year)
Theory Teaching	137	142	144	138	132.5	130	144	155.5	159.5
Productive Practice	22	22	20	42	44.5	8+67	11+45.5	14+45	15+47
Teaching Practice	0	0	4	0	1	0	0	0	0
Graduation Design	20	17	17	15	40	14	19	27	22
Examination	31	30	29	22	23	21.5	23.5	21.5	20
Rectification	0	0	0	6	7	0	2.5	5	0
Vocation	41	45	38	31	22	40.5	33.5	36	40.5
Total	251	256	252	254	286	261	279	304	304

Source: 方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。Fang,Huijian，Zhang，Sijing eds. Tsinghua University. Beijing:Tsinghua University Press,2001

At that time, quite a few Soviet experts had totally different opinions. They believed that schools could not cultivate qualified engineers after the schooling time of theoretical courses was reduced and were afraid that universities would be changed into secondary technical schools. At that moment, Tsinghua University had recognized that the reduction of theoretical teaching would affect the quality of graduates, thus it adopted the method of "evening up" (making up missed lessons which were the result of labor and political movements according to requirements of teaching plans) to make up as much as possible.

On the whole, the reform of the teaching system at that time did not touch the roots of the Soviet teaching system including the majors, teaching plan and teaching and research groups introduced in early years. However, the trend of education reform was to use many informal teaching systems to substitute the already-established formal teaching systems.

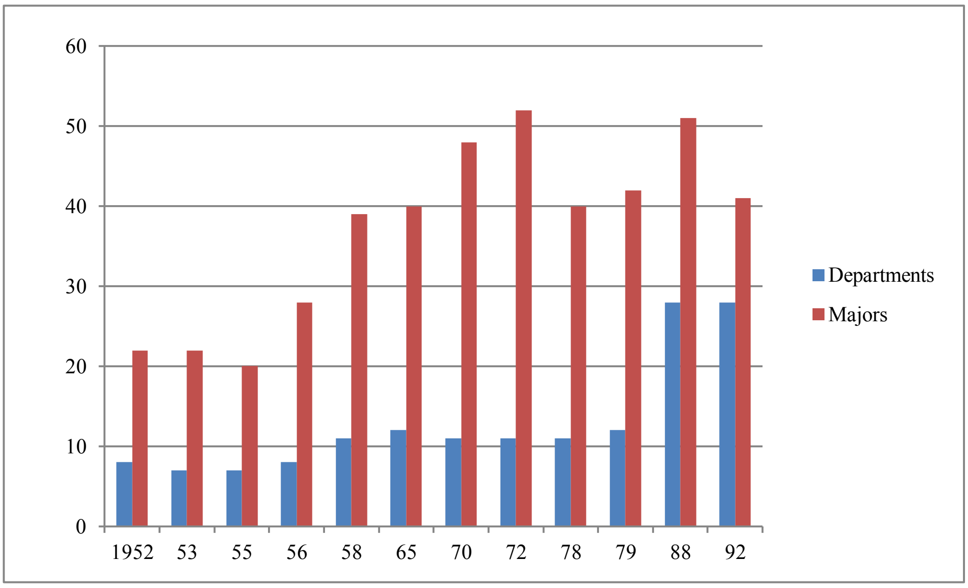
3.4.1.4 Recovery of engineering education

After the recovery of the unified enrollment system of nationwide higher educational institutions in 1978, Tsinghua University started to rethink the change of subject setting and cultivating models in place since the founding of the nation. Under the tide of the recovery and reorganization of education sectors, Tsinghua University also applied itself to recovery and reconstruction in two aspects: 1. The adjustment of departments and major subjects; and 2. The reinforcement of the scientific research ability of the school.

Through recovery and reorganization, Tsinghua University basically recovered to the scale - 12 departments and 40 majors - it was before the Cultural Revolution. In addition, since universities in Beijing were short of teachers for basic courses and basic technical courses, Tsinghua University built seven new classes for teachers including classes in electrical engineering, electronics, mathematics, physics, chemistry, mechanics and middle school education. Since the 1980s, Tsinghua University adjusted disciplines three times, in 1980, 1984, and 1989 respectively. The adjustments focused on the long-standing problems of the narrower coverage of majors and unreasonable specialty structure so as to improve the active adaptation of personnel of different majors to social requirements of engineers.

Tsinghua University had created a group of science majors with a strong engineering application background. Meanwhile, it had also set a large number of economic management subjects and liberal arts majors to encourage students take turns to select courses of natural science and the humanities and social sciences. In addition, it combined some majors with similar contents, for example, the three majors in the department of electrical engineering, (electricity generation (power system and automation), high voltage (high voltage technique and information processing), and electrical machine (electric machine and its control) were combined into electrical engineering and automation, connecting the three independent majors and strengthening courses of mechanics, machinery and thermal engineering to broaden the construction of basic courses of professional skills. Therefore, students could shift between several majors. With casting, pressing and welding in the department of machinery combined into the major of "mechanical engineering" and majors in metallic material, inorganic nonmetallic materials and nuclear material science in the departments of material science and engineering combined into a major of materials science and engineering, the division between majors further faded away.

Figure 3.3 Numbers of Departments and Majors during 1952-1992 at Tsinghua University



Source：方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。Fang,Huijian，Zhang，Sijing eds.: Tsinghua University. Beijing:Tsinghua University Press,2001

Adopting the credit system and the schooling time system, the teaching plan added optional subjects, limited optional subjects and optional subjects relevant to the major besides compulsory professional subjects. Limited optional subjects mainly included professional basic subjects and basic subjects; optional subjects were mainly comprised of practical basic subjects and tool subjects; and professional subjects were included in optional subjects related to the major. Taking the five-year teaching plan of the major of electrical engineering and automation as an example, in the first year, schools opened up compulsory courses like the history of the Chinese revolution, English, law, chemistry, advanced mathematics and engineering drawing; in the second year, physical experiments were added besides advanced mathematics, physics, chemistry and English; in the third year, students mainly studied required courses set by the department, including engineering mechanics and probability statistics, while limited courses could be chosen from English for science and technology, British and American literature, a second foreign language, Russian, Japanese, and readings for CET or even higher; in the fourth year, students should attend a compulsory course on Marxist philosophy required by the school, a compulsory course on computing methods required by the department, and basic courses included in limited compulsory courses such as steady-state analysis of electrical power systems, transient analysis of electrical power systems, power electronics, electrical drives and control, electric isolation testing technology, the principle and application of appliances (students had to at least choose five of these). In the last year, students mainly had optional subjects related to the major, including professional courses of the four directions in electrical engineering and automation; everyone had to choose four courses related to the major and one course in other directions. In addition, optional courses were chosen from foreign languages, new sciences, professional basic courses and professional courses. According to the table, from the aspect of course arrangement, we can see that the first and second year were focused on the study of public courses and had no majors; a few basic courses related to the major were added in the third year; and professional basic courses and professional courses were opened up in the fourth and fifth years by means of the elective system which was used to stress the cross-subjects of different directions and personal interest. The setting of optional subjects put more emphasis on the expansion of the major, cross-disciplinary majors, and in-depth study of professional knowledge. Obviously, from the setting of professional courses, the reforms of teaching plan during the 1980s-1990s were inclined to the regression of general education.

Another direction of the reforms was adjustment of location in cultivating personnel. In 1978, Tsinghua University recruited postgraduates again. After the issue of academic degree systems in 1980, the levels of engineer training were clearer. In November 1984, suggestions were agreed on strengthening the cultivation of engineering postgraduates submitted to the Ministry of Education by Tsinghua University along with 11 higher engineering colleges including Xi'an Jiaotong University, and pilot work was then carried out. Later, according to the "Notice on Strengthening the Cultivation of Engineering Postgraduates" issued by the State Education Commission in June 1986, Tsinghua University intensified its efforts to cultivate engineering postgraduates and transported engineers specialized in research and development to industrial enterprises, engineering construction units and other companies. Meanwhile, Tsinghua University returned to the university task of teaching and scientific research. By 1993, Tsinghua University had undertaken over 700 key national tasks at different stages, and students of master degrees or doctorate degrees were involved in research and development. At the beginning of the 1990s, with the development of scientific and technological work, major scientific and technological projects increased; for example, in 1993, the project of "the design, development and manufacture of heavy equipment of the plate heat exchanger factory" worthy of RMB 12,200,000 was signed by the department of mechanics, and the project of "engineering development of the computer trading system in Beijing Commodity Exchange" worth RMB 14,320,000, was signed between the department of computing and Beijing Commodity Exchange. This trend of industry-university-research cooperation was gradually welcomed in Tsinghua University. Furthermore, as the model for domestic multi-field polytechnic universities, Tsinghua University provided an example to other schools in cultivating engineers.

Table 3.7 The setting of majors in machinery disciplines at Tsinghua University during 1937-1989[178]

[178] Based on Fang,Huijian，Zhang，Sijing eds. : Tsinghua University. Beijing: Tsinghua University Press,2001:71-74.

<table>
<tr><th colspan="2">1937-1949</th><th colspan="2">1952</th><th colspan="2">1965</th></tr>
<tr><td>Discipline</td><td>Major</td><td>Department</td><td>Major</td><td>Department</td><td>Major</td></tr>
<tr><td rowspan="10">Mechanical Engineering</td><td rowspan="4">Power Engineering</td><td rowspan="8">Mechanical Manufacture</td><td>Mechanical Manufacture</td><td rowspan="5">Metallurgy</td><td>Casting machine and equipment</td></tr>
<tr><td>Metal-cutting machine and equipment</td><td>Metal processing machinery and equipment</td></tr>
<tr><td>Casting Machine, casting engineering</td><td>Welding machine</td></tr>
<tr><td>Metal working</td><td>Metal science and heat treatment equipment</td></tr>
<tr><td rowspan="3">Mechanical Manufacture 1936</td><td>Welding technology and equipment1953</td><td>Construction of metallurgy andmaterial1961</td></tr>
<tr><td>Metal heat treatment1955</td><td rowspan="3">Precision instruments machinery manufacture</td><td>Mechanical manufacturing process</td></tr>
<tr><td>Engineering Physics1955</td><td>precision instrument</td></tr>
<tr><td rowspan="3">Aeronautical engineering 1934</td><td>precision instrument manufacture1958</td><td>optical instrument</td></tr>
<tr><td rowspan="2">Power Machine</td><td>Automobile</td><td>Power machine</td><td>Boilers ect.</td></tr>
<tr><td>Thermal power equipment</td><td>Agricultural machinery</td><td>automobile and tractor</td></tr>
<tr><th colspan="2">1969-1976</th><th colspan="2">1978</th><th colspan="2">1989</th></tr>
<tr><td>Department</td><td>Major</td><td>Department</td><td>Major</td><td>Department</td><td>Discipline</td></tr>
<tr><td rowspan="5">Machinery Manufacture</td><td>Automobile design</td><td rowspan="4">Mechanical engineering</td><td>Casting machine and equipment</td><td rowspan="4">Mechanical Engineering</td><td rowspan="4">mechanical Engineering</td></tr>
<tr><td>Casting machine and equipment</td><td>Metal processing machinery and equipment</td></tr>
<tr><td>Processing machinery and equipment</td><td>Welding machine</td></tr>
<tr><td>Welding machine</td><td>Metal</td></tr>
<tr><td>metallic material</td><td colspan="4" rowspan="4"></td></tr>
<tr><td rowspan="3">Precision instruments</td><td>machine tool design and manufacture</td></tr>
<tr><td>optical instrument</td></tr>
<tr><td>Gyroscope and navigation instruments</td></tr>
</table>

3.4.2 Engineering college - Beijing Institute of Electric Power

3.4.2.1 Secondary technical schools

Beijing Institute of Electric Power originated from the School of Electricity which was established to meet the urgent needs of the electric power industry in 1950. It was subordinated to the electric power bureau of the central fuel industry with the duty of cultivating skilled workers relevant to electric power. In October 1953, the fuel industry changed its name to Beijing Institute of Electric Power in order to unify the name of polytechnic schools related to electric power. The institute had four majors, namely, machinery, electricity, furnace, and chemistry. Professional courses were mainly undertaken by technicians and engineers from factories and the bureau of electricity. With no teaching programs, the key points of each course were decided by the expertise and interest of teachers. Later, it gradually learned from Soviet higher education. In September 1956, the school employed Soviet expert P. W. Popov as advisor to the principal. During his stay at the school, he introduced a whole set of experience of Soviet secondary technical schools, implemented teaching plans, organized teachers to learn and study Soviet textbooks and teaching programs, planned lessons, organized public model lessons, added productive practice into teaching plans, and twice arranged productive practices in the three years (six weeks of practice at the end of the second semester in Grade 2 and eight weeks of practice before graduation examination in Grade 3).[179] Detailed requirements for practice were put forward by the teaching office of the school, and practice outlines of each major should be made, including practice contents, goals and requirements. Students should keep a daily record during practice, and score of practice was assessed according to practice records.

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[179] 华北电力大学校史编写组编著：华北电力大学校史 1958-2008，北京：中国电力出版社。North China Electric Power University History Editorial Board ed.: History of North China Electric Power University 1958-2008, Beijing: China Electric Power Press.2008:77.

3.4.2.2 Specialized higher educational institutions in a particular industry

After the general line of "going all out, aiming high, and building socialism more rapidly and economically" was put forward by CCP in May 1958, the Great Leap Forward was carried out in the whole country. In September, the "Instructions on Educational Work" issued by the Central Committee of the Communist Party of China and the State Council stipulated allowing all qualified young people and adults to receive higher education in about 15 years and popularize higher education in 15 years.[180] In order to realize the goal, measures made included: 1. Delegating administrative authority to higher educational institutions; 2. Requiring provincial ministries and commissions to encourage the establishment of schools. In this way, the number of local engineering schools increased rapidly.

The Great Leap Forward was one stage of the rapid development of higher education. The development patterns included renovation of old schools, the establishment of new schools and the renaming of schools with secondary technical schools. In 1956, Jiang Nanxiang put forward the method of "renaming schools with secondary technical schools" when he elaborated shortcomings of the "renovation of old schools" to the Central CCP. In addition, he proposed choosing some relatively good secondary technical schools and ordinary secondary schools, providing them with help, changing them into junior colleges with 2-3 year education, and then improving them to be able to complete with higher educational institutions. With so many merits, the method would not only damage the vitality of higher educational institutions, but could promote and encourage positivity of these secondary schools.[181] The Beijing Institute of Electric Power was a good example of this.

With the popularity of the Great Leap Forward in the whole country in May 1958, the

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[180] 胡绳：中国共产党的十七年，中共党史出版社，1991 年。.Hu Sheng: Seventeen years of Chines Communist Party," Party History Publishing House, 1991:364.

[181] 陈大白主编：北京高等教育文献资料选编（1949-1976），北京：首都师范大学出版社。2002。Chen Dabai ed.: Selected literature of Beijing Higher education (1949-1976), Beijing: Capital Normal University Press. 2002.

number of engineering schools increased dramatically. In September, the Ministry of Electricity & Water determined to make preparations for the establishment of Beijing Institute of Electric Power on the basis of Beijing Electric Power School. In November, the Ministry of Electricity & Water published the 361 document which declared that it determined to run a higher school based on Beijing Electric Power School with the name of Beijing Institute of Electric Power. The work was undertaken by the Technical Improvement Bureau under the centralized leadership of the Authority. Thus, a new school with the main task of cultivating senior technical personnel for electric power construction was listed in higher educational institutions.

In the early days of the establishment of the institute, the work of the institute mainly included a college and secondary technical school (Beijing Electric Power School was changed into the office of secondary technical school of the institute). In March, 1959, the Electricity & Water Authority made it clear that the office of secondary technical school subordinated to Beijing Power Administration was entrusted to Beijing Institute of Electric Power and located within the campus of the school. In addition, its teaching and other detailed work were arranged by the institute.

At the beginning of its establishment, the undergraduate college set up four majors, including electric machine and appliance manufacturing, power network and electric system in power station, thermal power installation, and power plant chemistry, and the education lasted for 5 years. By 1960, the school set up two majors, namely, power system automation and telemechanization (later renamed as power system relay protection and automation) and automation of thermal process in power station (renamed as thermo technical measurement and automation). However, the major of power plant chemistry was incorporated into Wuhan Institute of Water Resources and Hydropower. In September 1961, the three majors in Harbin Institute of Technology were incorporated into Beijing Institute of Electric Power, namely, power enterprise economy and organization, high voltage techniques and power networks and electric systems in power station.

The new teaching scheme was in line with characteristics of higher vocational education with the purpose of cultivating personnel according to direct demands of the industry. In subject construction, majors were set up according to production flow. In fact, the secondary technical school was more similar to universities in a certain industry whose task was to cultivate professional personnel for the Electricity & Water Authority.

Compared with Polytechnic Universities, higher educational institutions in a certain industry of this kind were more likely to be affected by national policies, and thus to change professional emphasis and teaching plans. In October 1969, the business group of the State Council and the military control commission of the Bureau of Water Resources and Hydropower determined to move Beijing Institute of Electric Power to Handan, Hebei according to the strategy of "evacuating combat readiness". In October 1970, the core team of the Revolutionary Committee in Hebei Province determined to move Beijing Institute of Electric Power to Baoding in December with the name of North China Institute of Electric Power, with the school under the leadership of the province and the Authority with the guidance of the province as priority. In December of the same year, the school reopened with four majors, namely, electricity generation, electric automation, thermal power and thermal automation and recruited 122 worker-peasant-soldier students, among whom 87 had obtained junior high school education, 24 senior high school education, and 11 below junior high school education. Since the expansion of revolution in education, education was affected by more political factors. The school history of North China Electric Power University reads: Peasant-soldier students attended entrance education of half a month after the enrollment, and received camp and field training of a month according to the notice of "camp training of schools in large and medium-sized cities" issued by the central CCP. The camp and field training included activities of memorizing tradition and learning from tradition to strengthen the ideological education of students. During the camp and field training, teachers and students completed the tasks of autumn harvest. When some students helped peasants to thresh rice in the field of a Zhang family in Anxin County, the power went out, thus they had to stop their work. A community member said to them, "since your school is related to electric power, can you make more electric power?" Hearing the words and seeing the anxious expression of community members, they could not calm down for a long time. Since the abolishment of some recruitment restrictions, some old workers with junior high school education degrees were enrolled. Students of this kind had difficulties in learning foreign language, and in order not to affect the study of basic professional courses, the school had to make an interim measure of exempting the study of foreign languages. Teachers sighed that they could not see the vitality of the enrollment method. Moreover, the school year was cut down to 2-3 years, contents of the teaching material used were less than that of old textbooks, and courses seemingly unrelated to the major were ruled out, denying the continuity of the approved and effective curriculum setting. In teaching, the school adopted methods of "running the school with the door open", "teaching with typical products", and "learning by doing", displacing teaching with labor. For example, teachers gave lessons to students majoring in electric automation with the typical products of relay protection devices, students majoring in thermal automation went to the second instrument and meters factory in Beijing to study with control apparatus of thermal meters, and students majoring in electricity generation and thermal power mainly went to units like power stations and transformer substations to study. The main form of "running the school with the door open" was labor, and methods included "learning by doing" and "workers and masters giving lectures". Results of teaching methods of this kind were that the cultivation of engineers in production could just reach the level of technical workers, theoretical knowledge was insufficient to solve technical matters in production processes, and technological innovation was surely beyond their ability.

3.4.2.3 Multi field schools with advantages in industry

In February 1978, the State Council endorsed a Report on Recovering and Perfecting Key Higher educational institutions of the Ministry of Education and determined the first group of key higher educational institutions after the Cultural Revolution. As the educational base of cultivating personnel for electric power industry, the institute was listed in the new 28 key higher educational institutions in the whole country. In September, approved by the State Council, the institute was under the leadership the Electricity & Water Authority and Hebei Province with the Authority as the main leader, and the school's name changed from Hebei Electric Power College into "North China Electric Power University". In the 1980s, the dilemma of industrial colleges such as North China Electric Power University was how to get rid of the tendency of school-running pattern to that of vocational schools. The delegation of power from the Ministry of Education looked like a double-edged sword; on the one hand, it let schools get some rights in reforming their own systems, on the other hand schools could not carry out their reforms due to insufficient capital investment by depending on the allocation of national education expenditure unilaterally, and in addition, the update of teachers and teaching research equipment needed capital support.

Fortunately, after the 1980s, industrial universities with distinct professional features like North China Electric Power University had more advantages over polytechnic universities in their combination of production and study. Since the university was closely related to industries, it was strongly supported by them. Meanwhile, the university put great emphasis on the transformation of applied research and scientific research achievements, providing the conditions and basis for the industry to develop common technology and solve key problems. The pattern of virtuous cycle developed a combination method between industries and universities. The school actively met the needs of reform and development in the electric power industry in personnel and scientific technology, and it mainly served as the main battlefield of electric power economic construction. Furthermore, it broke the old school-running system of "cutting up links among departments and regions" to strengthen its awareness and function in serving the local and the society. Aiming at the demand situation of the industry in personnel, the school carried out the work of talent cultivation and scientific research. The school and electric power enterprises had established a cooperation mechanism of talent cultivation. Considering the urgent need of the industry in technical personnel, the school implemented order-oriented cultivation, becoming an experimental plot of personnel training mode innovation of the Ministry of Education. The school established an off-campus practice base of undergraduates in electric enterprises, a talent training base of practical teaching in power stations, a talent training base for power grid practical teaching and an education centre for nuclear power engineering practice which were listed in state-level engineering practical education centers; meanwhile, it established over 50 postgraduate workstations, employed engineers in enterprises as external tutors for postgraduates, and carried out the strategy of "cultivation with two tutors" for postgraduates. The school was ranked in the first group of innovative units in cultivating engineering postgraduates.

At the beginning of the 1990s, the school formed the Beijing campus structure of "running schools with two colleges" with the School of Economics and Management of Beijing Institute of Hydraulic and Electric Engineering and Beijing Postgraduate Faculty of North China Electric Power University, which had enhanced the school's comprehensive strength with the focus on engineering (see table 3.8). On the basis of maintaining its advantages and characteristics in applied engineering subjects, to meet the needs of modernization of electric power in the economy and management-based personnel, the school increased its strength in cultivating managerial engineers by setting up majors like management engineering, technical economics and industrial foreign trade while cultivating the technology-based engineers urgently needed in the electric power industry. Therefore, a new subject pattern featuring mutual penetration and coordinated development among arts, science, economy, law and management with the focus on engineering was established.

Table 3.8 Disciplines and Majors at the Beijing Institute of Electric Power 1992

<table>
<tr><th colspan="2">Disciplines</th><th>Undergraduate Majors</th></tr>
<tr><td rowspan="14">Engineering</td><td>Thermal and nuclear energy</td><td>Thermal Engineering</td></tr>
<tr><td rowspan="2">Electricity</td><td>Power System and Automation</td></tr>
<tr><td>Electrical technology, industrial automation</td></tr>
<tr><td>Electronics and Information</td><td>Information engineering, computer science and application</td></tr>
<tr><td></td><td>Automatic control, communications engineering</td></tr>
<tr><td>Instruments and Meters</td><td>Detection techniques and instrumentation</td></tr>
<tr><td rowspan="3">Machinery</td><td>Machinery manufacturing technology and equipment</td></tr>
<tr><td>Design and manufacture of machinery</td></tr>
<tr><td>Machine Electronic Engineering</td></tr>
<tr><td>Environment</td><td>Environmental Engineering</td></tr>
<tr><td rowspan="2">Management</td><td>Management Engineering, Technical economy</td></tr>
<tr><td>Industry and Foreign Trade</td></tr>
<tr><td rowspan="2">Economics</td><td>Economics</td><td>Labor economics, taxation, auditing</td></tr>
<tr><td>Business Administration</td><td>Accounting, Business Management</td></tr>
<tr><td rowspan="2">Law</td><td>Law</td><td>Economic Law</td></tr>
<tr><td>Political science</td><td>administrative science</td></tr>
<tr><td>Literature</td><td>Foreign Language and Literature</td><td>English</td></tr>
<tr><td>Science</td><td>Mathematics</td><td>Probability and Statistics</td></tr>
</table>

Source: North China Electric Power University website: http://www.ncepu.edu.cn/xkjs/index.htm

Chapter 4 Careers and vocational status

In 1949, the leaders of China had a rough idea about how to include scientists and engineers in using science and technology in new China. The idea was based on the nationalization of scientists and engineers, and it put more emphasis on their sense of organization rather than their individual creativity.

Among Chinese intellectuals, the vocational and living status of professionals had been an issue in Chinese scientific and technological policy for many years, which is shown by the ever-changing policies introduced in Chapter 2. As a group with critical skills in society, engineers should have a certain degree of social autonomy if they want to give full play to their specialties. Meanwhile, since engineers live in society, their self-management and living standards are closely related to changes of national policy.

Since the 1950s, the CCP devoted itself to making scientists and engineers obey the idea that science and technology should be under the management of the Party. This obedience led to the reconcilement of professional values and the party's values, for which scientists and engineers submitted to bureaucratic and political management and obligation at the expense of autonomy. In return, the CCP gave them preferential treatment. This was similar to regulatory modes existing in some research institutes that some non-higher schools of the Soviet Union and America belonged to. Thus, we should assess scientific and technical workers' professional requirements, work environment, use of time, goals and stimuli according to the specific situation. In this chapter, we will center on engineers' activities in occupational areas and characteristics and the variation of their professional activities in the current system since the founding of the nation.

4.1 Professional fields

There is no dependable data and analysis of engineers before the Cultural Revolution. Regardless of this uncertainty, we can roughly estimate the conditions of engineers and technicians according to the speeches of leaders and authoritative newspapers. This estimation may not be too far away from the fact.

Premier Zhou Enlai commented in 1956:

"Though there are little more than 31,000 engineers of different grades in China, many of the 63,600 technicians who have graduated from the universities were long ago promoted to the position of engineer."[182]

Although the data is not precise, we can know that the number of engineers in the 1950s was about 30,000, far from the number needed by Chinese industrialization. With the development of industrialization and the expanding enrollment in engineering education, the number of people whose work related to engineering technology increased steadily. In spite of the 10-year long Cultural Revolution, from the statistical data of professional talents in 1978, the population of engineering personnel was on the rise. The shortage of talents resulting from the Cultural Revolution did not reveal itself immediately, it shows that there was a time lag between engineers' education and employment.

According to the *Statistical data of Chinese Science and Technology during the 40 Years from 1949-1989*, edited by the Statistics Division of Science and Technology of the National Statistics Bureau, by the end of 1988 the number of scientific and technical workers (including workers with primary, intermediate or senior professional titles) in natural science in state-owned units reached 9,661,000, including 4,375,000 engineering technicians, 502,000 agricultural technicians, 2,468,000 health technicians, 307,000 scientific researchers, and 2,009,000 teaching staff, amounting for 45.3%, 5.2%, 25.5%, 3.2% and 20.8% respectively. At the end of 1988, in the 10,738 large and medium-sized industrial enterprises, there were 1,585,000 engineering technicians, accounting for 6% of the total number, and 797,000 technology developers, including 269,000 scientists and engineers, making up 33.7%. The number of scientists and engineers was 102 in every

[182] Zhou Enlai, Report on the Question of Intellectuals, at a Meeting Held Under the Auspices of the Central Committee of the Communist Party of China to Discuss the Question of Intellectuals. Beijing: Foreign Languages Press,1956, Delivered on January 14, 1956:5.

10,000. By the end of 1988, since 5,119 large and medium-sized industrial enterprises had established their own technological development institutes, the number of institutes reached 5,525 in which there were 273,000 technological developers, including 114,000 scientists and engineers, amounting for 41.6%.[183]

Although the data does not state the exact proportion of engineers to scientific and technical workers, from the proportion of scientific and technical workers including engineers, we can know that over 90% of engineers had a job in the following four fields: Industrial enterprises, government organs (including administrative management institutions as well as non-academic research institutions and research and development institutions which were affiliated to the government), higher educational institutions, and in the field agriculture. Most engineers were in the field of industry, followed by agriculture and then healthcare, under the management of government organs. Based on the statistical data, in this chapter we will analyze the vocational status of engineers in these three main industries.

4.1.1 Agriculture engineers: Peasant scientists vs. agriculture engineers

Before 1949, most people made a living by directly depending on agriculture, but agricultural growth was subject to limited arable land and backward agricultural technology. With the population growth in China, supply was met by changing approaches instead of innovating mechanical technology. Since land was used to plant new crops like corn, peanuts, sweet potatoes and tobacco as well as improved cotton, the average output and value of per unit land gradually increased. Moreover, at that time, the development of the agricultural economy mainly depended on investing plenty of rural labor as well as unused arable land. The shortage of investment in science and technology shaped the extensive rural economic growth model. With the development of the rural economy, the marginal

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183 中国统计局：中国科学技术四十年 1949-1989（统计资料）。北京：中国统计出版社。1990：第一个统计表。China Statistics Bureau, Science and Technology Statistics Division: Statistics On Science and Technology of China 1949-1989,Beijing: China Statistics Press, chart 1:191-199.

utility of improving output by simply increasing traditional elements was very low, resulting in traditional agriculture's distinct lack of growth momentum. After the CCP took power, the idea of industrialization on the basis of emphasizing and accumulating agriculture won wide support inside the CCP. In the debate between agriculture and industry, the CCP was obviously inclined towards industrial development that could rapidly show the superiority of socialism. Compared with high investment in industry, scientific and technological research in agriculture appeared to be insufficient.

Since the implementation of the first Five-Year Plan, the country had carried out the policy of advancing industrial technology with the major objective of realizing the strategy of "forging ahead". In agriculture, the country began to establish scientific agricultural research institutions. In 1956, the Party's central committee issued the first scientific and technological development plan, the "National Long-Term Development Plan in Science and Technology", which initiated an upsurge in agricultural technology. Since then, all counties explored changing the traditional situation of "living at the mercy of the elements" and sought new ways to develop agriculture.

In 1951, areas in north and northeastern China ran stations for popularizing agricultural techniques and began to set up supportive networks for agricultural science and technology. In 1952, some counties and regions established stations for popularizing agricultural techniques, and areas at a county level set up cooperative agricultural production boards. In the late 1950s, a four-level agricultural scientific experiment network was built in the countryside. This network was composed of agricultural science institutes at the county level that, in collaboration with higher-level, agricultural scientific institutes, formed what the Chinese call "the backbone". The other three levels are stations, teams and groups at the commune, production brigades, and production team levels respectively. The network played an important role in promoting agricultural development and also included forestry, animal husbandry, sideline production, and fisheries, in addition to farming crops. However, one should realize that the importance of the network lay as much in solving production problems as solving problems encountered in research. Thus, the network's value lay in its ability, jointly with professional agricultural science workers to gather data, study breeding and cultivation techniques, and, finally, to propagate the seeds over large areas.

As a member of US Plant Studies delegation said in 1974: "If you could hybridize the Indian and Chinese agricultural research and extension systems, you would have a very good system. India now has some very sophisticated research capacities and is very poor between the research organizations and the farmer. Between them and the farmer they are weak whereas between such organizations and the farmer China is strong. But China does not have anything behind it. Both of them have great gaps, and the Chinese system has a great gap in the more sophisticated work. It is probably easier to create the research part once the extension part is in place, however, than vice versa. "[184]

Due to the shortage of technicians and engineers in agriculture, the work of agricultural science and technology lagged far behind the networks used to extend agriculture. In the 1950s, scientific and technological agricultural development had not been fully understood by China. Agriculture engineers were more like mechanical engineers, civil engineers, biologists and botanists who worked in agriculture. Moreover, these people constituted a small number and were generally centered on agricultural colleges and agricultural research institutes. Since the development and popularization of agricultural technology lacked ample capital and manpower, advanced agricultural technology still remained in institutes in spite of complete networks.[185]

The party had also noticed the problem; thus, in March 1958, Nie Rongzhen (聂荣臻), the Vice Prime Minister, explained in the fifth meeting of the National Scientific Planning Committee that science must serve the great leap in production to the scientific community.

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[184] Jon Sigurdson: Technology and Science in the People's Republic of China, An Introduction. British Library Cataloguing in Publication Data.1980: 103-104.

[185] 农业工程师的关键作用。美国农业部科技局副局长、国际农业工程学会主席Edminister先生参加中美农业科技合作工作组于1980年元月与中国农业工程研究设计院的部分同志座谈。谈话简记。The key role of agricultural engineers :Records of Mr. Talcott W. Edminster (the Administrator in the United States Department of Agriculture) speech on the conference of agricultural cooperation work between China and USA in Jan 1980.

He also said, "To realize the great leap of science in our country, we must make clear the fundamental principle that science has to serve to production. If we did not know it, scientific undertakings in our country would get lost".[186] The spirit of the meeting was first answered actively in the scientific agricultural circle. On March 15th, the Chinese Academy of Agricultural Sciences held a mobilization meeting. A week later, the Academy selected over 280 researchers (accounting for 2/3 of the total number) from subordinated institutes to form six scientific teams to study the control of plant diseases and insect pests, farming and epidemic prevention in livestock and poultry, and improvement of agricultural machinery and tools in counties in order to promote agricultural production. With the upsurge of the "Great Leap Forward", some research and development institutions in the Chinese Academy of Sciences raced to take part in the activity. Furthermore, some disciplines unrelated to agricultural production also frantically sought research topics conducive to production and some scientific workers even tried to change their jobs. For example, Shou Zhenhuang (寿振黄), a researcher who studied birds at the Institute of Zoology of the Chinese Academy of Sciences, shifted to studying animals in order to meet the needs of the government and people.[187]

In addition, the great victory of the "mass line" in the revolution was used in the field of production. After Chairman Mao put forward the slogans, "get rid of superstition", "think and do boldly" and "the lowly are clever and the noble are stupid", and with the wide popularization and promotion of mainstream media, farmers were mobilized, while the social identity of the value of agricultural engineers and scientists was severely derogated.

Firstly, it reflected itself in technological competition in the growth of agricultural production. At the beginning of the "Great Leap Forward", the agricultural scientific circle

[186] 聂荣臻：国家科技计划委员会第五次会议上的讲话。引自：中国科学技术协会编辑委员会：中国科技协会。当代中国出版社。1984：第65页。Nie Rongzhen: Speech on the scientific community in the fifth meeting of the national scientific planning committee. Cite from: China Association for Science Technology.1984:65.

[187] http://www.baike.com/wiki/%E5%AF%BF%E6%8C%AF%E9%BB%84

regarded pilot farming as the major way to implement the policy of "linking theory with practice". Experts in rice cropping, rice pests, seeds and soil from the Zhejiang College of Agriculture planned a high yield of triple cropping rice and to increase the rice yield per acre of over 727 Jin (斤) in 1957 to 1,500 Jin.[188] However, farmers' more exaggerated "high yields" meant that the pilot farming projects were too far behind to catch up. In Zhejiang Province, when local leaders reported that the average fertilizing amount of the province in that year was 2,000 Dan (石),[189] Naykin, a famous Soviet scientist in chemical fertilizer said politely, "That was 750 times as much as in the Soviet Union". In the meeting held in the agriculture department of Hebei Province, although Soviet experts thought the official data of the products could be wrong, they chose to keep quiet, because no one would trust them under that circumstance. Because of the Mass Line, the CCP also thought that scientists and engineers should listen to farmers, and let researchers focus on summarizing the experience of farmers for high yield. Moreover, scientists in the Chinese Academy of Sciences were ordered to launch the research topic of "what to do with too much food?" when "high yield" spread all over the world. Before long, however, the country witnessed the "great famine". The cruel reality that some people had died for lack of food not only declared the end of the project "what to do with too much food?" at the halfway point, but instigated a research task of "how to deal with the shortage of food".[190]

Secondly, under the Mass Line policy, there was too great an emphasis placed on self-taught farming experts. Scientific and technical workers were encouraged to learn "scientific theory" from self-taught experts. Take, for example, Li Shimei (李始美), a farmer in Xinhui County, Guangdong Province, who stopped his education after finishing

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[188] Catty is a traditional Chinese unit of mass. In mainland China, the catty has been rounded to 500 grammes and is referred to as the market catty (市斤) in order to distinguish it from the "metric catty" (公斤), or kilogram, and it is subdivided into 10 taels rather than the usual 16.

[189] Traditional Chinese Unit of capacity,1 dan= 100L.

[190] 薛攀皋：自然科学研究盲目听命政治的教训—荒唐的科研课题“粮食多了怎么办”。炎黄春秋，1997年第八期。Xue,Pangao：Lessons that Science Research blindly obey political Order-- absurd scientific research "what to do with too much food?".Yanhuang Chunqiu,1997,Vol.8.24-26.

Grade 1 in junior high school. According to his own biography, from January 1953 to June 1956, he started reading documents and books related to entomology and termites, then studied carefully prevention and treatment measures against ants and finally acquired a set of effective methods to eradicate termites, after cracking more than 1,800 termites nests and understanding the secrets of the insects. After finding out successful methods to exterminate termites, Li imparted the methods to students in classes held in the town's people's government instead of holding onto it privately.

In December 1957, he, along with a termite eradication group, made efforts to eliminate all termites in the town over two months at the expense of only 376 Yuan. Because of his contribution, he was titled "an expert in termite eradication" at the age of 35 in 1958. On May 20 1958, at the invitation of the Chinese Natural Science Association, Li popularized his methods among scientists in Beijing. His visit to Beijing was warmly welcomed. In the afternoon of the same day, Li gave the first report presided over by Wu Youxun (吴有训), vice-chairman of the Chinese Natural Science Association and vice-president of the Chinese Academy of Sciences, and then exchanged experience with entomologists. Giving high praise to Li's studies, Chen Shixiang (陈世祥), director of the Insect Institute of the CAS and president of the Chinese Association of Insects, considered his study a model for scientific work with greater, faster, better and more economical results and that it reflected the scientific road of socialism. He also firmly believed that the study of Li Shimei on termites had exceeded the world standard.[191] Zhang Zongbing, professor in Peking University and toxicologist, praised the success of Li as the result of "thinking, speaking and doing boldly" and argued that the study had gotten rid of conventions of general scientific work as well as superstitions. All entomologists and toxicologists believed the methods and opinions of Li were in line with the theory of entomology. Ultimately, Chen Shizhou announced that Li was approved by the council to

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[191] 科学工作者的榜样， 白蚁专家李始美到京作报告。人民日报， 1958-05-22。Great example for Youth Scientifical Workers,Termites Expert Shimei Li Gave Report in Berjing. People's Daily. May 22nd.1958.

become a member of the Chinese Academy of Insects.[192]

Li's achievements in scientific research were praised by three newspapers at a national level. High-level political public opinion of this kind was unparalleled for contemporary scientists in China. On June 20 1958, Sun Yat-Sen University offered him a professorship in the department of biology. On July 11 1958, at the proposal of leaders of the Insect Institute, the 8th executive meeting of the Chinese Academy of Sciences determined to employ Li as a researcher at the Insect Institute. It is worth mentioning that Li retired from the Insect Institute of Guangdong Province in the 1980s. During the 20 years before his retirement, his methods in eradicating termites were not obviously improved, his experience was not raised to a theoretical level, and many important issues and opinions proposed by him had not been verified. At that time, there were many other self-taught experts who were praised by newspapers and magazines. For example, the highest Party journal, Red Flag, published an article to present a 27-year old expert, Wang Baojing, the director of Fenghuo agricultural producers' cooperative in Suanquan County, Shanxi Province, with only two years education in primary school, who was employed as a contract research fellow by the Shanxi Institute of Agricultural Sciences.[193] In the article, it was said that he was a scientist in reality as well in name and that he was a 'new-type scientist', cultivated by the Party. On June 3 1958, the Agricultural Mechanization Institute of the Chinese Academy of Agricultural Sciences held a great engagement ceremony and employed 21 self-taught experts as contract research fellows.[194]

As analyst L. Orleans said, "Whereas political and social changes have permeated throughout the population, large segments of the rural population are still untouched by technological change."[195] When technical knowledge pertaining to agriculture had not

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[192] 蔡邦华：对于李始美同志防治白蚁报告的体会。昆虫知识。1958年第三期。Cai,Banghua: Understood from the report that how to control termite by Shimei Li. Knowledge of insects.1958.Vol.3.

[193] 青年农民能不能成为科学家。红旗，1958年5月。Is youth farmer able to become a scientist? Red Flag.1958.May.

[194] 科学并不神秘.人民日报, 1958-05-22.Science is not mythical. People's Daily. May 22 1958.

[195] L. Orleans: Research and Development in Communist China: Mood, Management and Measurement, An

gained a firm foothold in counties, competent farmers conforming to political propaganda became agricultural specialists and engineers; while all authentic experts lost their voice due to their political orientation. Some technicians were forced to give up the scientific attitude of seeking truth from facts, and some even "sincerely" considered farmers as masters unconsciously losing their sense of science and fawning on political needs in a special social environment. However, some scientists expressed their doubts. For example, in the "competition" during the Big Leap Forward, some repeatedly emphasized, "Farmers can say what they want, but academies of sciences must be practical and realistic, with a sufficient theoretical basis." [196] Unfortunately, these voices were lost in the value orientation of the mainstream.

The mass line could not be ignored, the People's Daily says in an editorial in 1978: "The results of the masses' scientific research and the experience of agricultural production models are rich resources for the scientist and engineers in scientific research. While scaling the heights of scientific and technological research, professional scientific researchers must also provide more theoretical and technical guidance for the masses' scientific research so that the masses can sum up their experience and improve their scientific research. "[197]

However, it was an obvious step forward that scientific methods should be adopted. Since 1979, China had quickened its speed in agricultural engineering. Firstly, the State Science and Technology admitted agricultural engineering as an applied technical science of China; the State Council gave permission to establish a Chinese Academy of Agricultural Engineering Research and Planning under the leadership of the Ministry of Agriculture; the same year, the Chinese Association of Science and Technology approved the establishment of the Chinese Society of Agricultural Engineering. In addition, a

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Economic Profile of Mainland China, US Congress Joint Economic Committee,Washington,1967.

[196] ××副所长谈科学家对李始美的看法.科学简讯,1958-07-19(第3期). 中国科学院档案.Interview about how scientists thought about Shimei Li by Vice the Deputy Director. Science Bulletin. July 19,1958,Vol.3. Chinese Academy of Sciences

[197] People's Daily, 7th editorial on agricultural science, NCNA, May 7 1978.

developmental planning of agricultural engineering was worked out. Besides irrigation and water conservancy as well as agricultural mechanization, Chinese agricultural engineers believed that we should expand the scope of work and carry out the following work: Agricultural electrification, agricultural building and environmental control, rural energy, projects of land utilization, process of agricultural materials, agricultural engineering economy, popularization of agricultural engineering, agricultural system engineering, application of electronic computer, remote sensing technology and other new technologies in agriculture.

However, things went to the other extreme. Yuan Longping, graduating from Southwest Agriculture College (now called as Southwest University) in 1953, conformed to the unified national distribution to work as a teacher in Anjiang Agriculture College in Huaihua, Hunan. Later the same year, he was distributed to do teaching work in Anjiang Agriculture College in the remote and backward Xuefeng Mountain in western Hunan. Since 1960, a rare disaster gave rise to a great nationwide famine. The 30-year old Yuan Longping, after learning that hybrid sorghum, hybrid corn and seedless watermelon had been widely used abroad according to some reports, started to conduct hybridization experiments in rice. After two years of experimenting and scientific data analysis, he wrote his first important paper, 'Male Sterility of Rice' which was published in the Chinese Science Bulletin in 1966. In the paper, he predicted that through further breeding, we could obtain the male sterility line, maintainer line (making the descendant keeping the characteristic of male sterility) and restoring line, realizing the mating of the tree lines, and that application of the first generation advantage of hybrid rice was possible, which would increase rice production dramatically.

In theory, Yuan had studied the genetic theories of Mendel and Morgan, but their theories were opposed to those of Michurin and Lysenko from the Soviet Union that were popular in China at that time. Being puzzled, he determined to verify the rationality of the two kinds of theories through experiment. The thoughts and methods of acquiring new products with genetic advantages through hybridization among crops were correct. Yuan realized the reasonability of using genetic advantages to study hybrid rice breeding. Therefore, he was determined to change the original research direction and try something new. In the several early years of his study, he guided assistants to perform over 3,000 hybridized combination experiments with thousands of rice varieties. In order to quicken the speed of breeding, changing time with space, he expanded the scientific research southward to Guangxi, Yunnan and Hainan, doing the study in Hainan in winter and spring, in Hunan in summer and in Guangxi in autumn. The study of hybrid rice was original, from its theoretical construction and formulation of technical solution to the design of its experiments. By 1974, the preparation of seeds succeeded and the advantage identification was organized. In 1975, under the support of the Party committee and the government of Hunan Province, a large-scale seed preparation succeeded which made it ready for wide popularization in the next year.

In the winter of 1975, the State Council made the decision to rapidly expand plant experiments and generalize hybrid rice and invested more into breeding with three generations in a year so as to popularize it as soon as possible. In 1976, the declared 2.08 million Mu (亩)[198] demonstration areas were used nationwide. By 1988, the area of hybrid rice reached 194 million Mu which accounted for 39.6% of the total area of rice, and its production made up 18.5% of the total output. Over 10 years, the area of hybrid rice in the whole country was 1.256 billion mu, which produced over 100 billion kilograms and increased the total output value to 28 billion Yuan, obtaining both huge economic and social benefits.[199] Later on, in 1988, hybrid indica rice was transferred to America as the first Chinese patent. In addition, more than 20 countries introduced hybrid rice seeds. The scientific achievements made by Yuan allowed China to advance the world level for three times in short stem rice, hybrid rice breeding and super hybrid rice breeding.

On June 27 1981, the contribution of hybrid rice was confirmed during the session of the 11th central committee CCP. Some important achievements were made in industry and

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198 1 Mu= 667 Square meters.

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transportation, capital construction, and science and technology, including the building of some new railways and the Nanjing Yangtze River Bridge, the operation of several large-scale enterprises with advanced technology, success in the test of hydrogen bomb and in the launching and return of man-made satellites, as well as the breeding and popularization of hybrid rice. On June 6 1981, Yuan was conferred the first special invention award with hybrid rice. On June 15 1984, the Hunan hybrid rice research center was established with Yuan as the director. In the same year, he was titled a "National young and middle-aged expert with outstanding contribution". In 1985, he was employed as the honorary president of Anjiang Agriculture College in Hunan and part-time professor of the Southwest Agricultural University. On October 15, he was conferred the gold medal and certificate for honor of "invention and creation" at the United Nations Intellectual Property Organization, his first international award.

However, despite being an expert in hybrid rice technology, he was repeatedly denied admission to the Chinese Academy of Sciences, which had started a great disturbance in society. Many people believed that the failure of Yuan Longping in being selected as an academician of the CAS reflected the academic circle's disrespect towards farmer scientists and contempt for their practical achievements. Later on, when talking about the reasons for Yuan's failure, Lu Yongxiang (路甬祥), the president of the Chinese Academy of Sciences said, "The reason for Yuan's failure in the selection was that the scientific circle including academicians has certain restrictions and biases in evaluating someone's achievements, and they mainly emphasized life sciences. They pay attention to whether someone has created new methods, ways or thoughts in the frontier domains of life sciences, which required evaluating him from the aspect of molecular biology. Since Yuan conducted scientific experiments with relatively traditional hybridization methods, he was not selected."[200] In 1995, a year later when the Academy divided into a science academy

[200] 路甬祥：自主创新与建设创新型国家。人民网强国论坛，"两会专区"。2008 年 3 月 14 日。Lu: innovation and building an innovative country. Qiangguo forum, the "two sessions area". March 14 2008.http://www.people.com.cn/GB/32306/54155/57487/7002741.html

and an academy of engineering, Yuan was selected as an academician of the Chinese Academy of Engineering. This tells us that society did not understand engineering and science, and placed an opaque distinction between scientists and engineers.

As the primary industry, agriculture held a special and important position in China. Every leader emphasized in government work reports that the steady growth of agriculture and the improvement of rural industrial structures were the foundation for the long-term stable development of the national economy, and it was urgent and important to strengthen agricultural construction. Engineers in agriculture were the key to realizing the modernization of agricultural engineering. However, the position of agricultural engineers did not match their importance. The notion that it was best to learn science, followed by engineering and literature, but the idea that you could go to agricultural schools with bad grades had become a deep-rooted part of Chinese cultural identity. In fact, in China, agricultural engineering was a new subject in a modern sense, different to traditional agricultural technology. Agricultural engineering needed to find its proper place in discipline classification, and agriculture engineers had to locate themselves and acquire attention as soon as possible.

4.1.2 Industrial engineers: Executors of technology transfer

From the aspect of technology history, the process of industrialization of a country needs entrepreneurship and the production of technology. China was especially week in these two aspects, thus successive governments acted as ‘entrepreneurs’, while the role of Chinese engineers who grasped technology and could let it take root in China through their activities in the current social conditions was particularly important. Taking the leading sector of industrial engineering as an example, in this section we will discuss the position and effect of industrial engineers in the process of industrialization.

At the beginning of the 1950s, China established a construction policy of giving priority to the development of heavy industry and the national defense industry, which not only reflected the needs of the national economy, national safety and social development, but also the effects of Sino-Soviet relations and the assistance of the Soviet Union. Since the first Five-Year Plan, the government identified heavy industry as the key to economic policies. After the policy of learning from the Soviet in all aspects in 1952 and the implementation of Project 156, some engineers employed by national government enterprises were excluded due to the revolution in ideology, while Soviet engineers were employed, alongside new technicians and engineers who had received Soviet training and engineers cultivated in new-type colleges were put in important positions. Production-oriented and field engineers centering on industrial enterprises were cultivated through an apprenticeship system. In Project 156, besides installing and operating major equipment, the Soviets also took the job of delivering designs, supplying equipment, submitting technological data, dispatching experts, and accepting interns. Enterprises cultivated field engineers through traditional methods such as commissioned training in engineering schools, lectures given within plants by Soviet experts, as well as the apprenticeship system. Research and development-oriented engineers were gathered in scientific research institutions.

After 1949, due to a serious shortage of technicians and engineers (in 1953 the proportion of skilled workers in the heavy industry sector was only 4.6%), and a serious lack of skilled workers.[201] Chinese machinery manufacturing engineers had no choice but to adopt the method of combining existing Chinese technology with advanced foreign technology. Chinese machinery equipment was acquired in two ways: One was by importing it from the Soviet or eastern European countries directly, and the other was through imitating by mapping or bringing in drawings.

The main method of making progress in technology depended on the assistance of the Soviets, which reflected itself in Project 156. Many enterprises brought in complete sets of heavy equipment from the Soviets - 4.6 million tons of rolling equipment, including a 1.150 mm blooming mill which was listed in the inventory of the Anshan Iron and Steel

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[201] 小岛丽逸：中国的经济和技术。劲草书房，1975 年。Kojima Reiitsu: China's Economy and Technology. Tokyo: Keiso Shobo. 1975:325.

Group and matched 850/750/500mm steel rolling mill set; the Beiman Special Steel Corporation brought in a 825 mm blooming mill and matched 500/350/280 mm bar mill; China First Heavy Industries introduced a 60 MN free-forging hydraulic press which was the biggest press in China at the time; the 447 Arsenal in Inner Mongolia introduced in 12.5 MN and 20 MN hydraulic press, and so on. Major technical tasks of the large-scale heavy machinery factories were assumed by Soviet engineers, including selecting plant sites, collecting basic data, designing (the Soviet party took on 70-80% of the design job), supplying equipment (the Soviet party took on 50-70% of the job), providing technical data for free, and guiding construction and installment as well as operation. Due to their over-dependency on Soviet assistance, heavy machinery enterprises placed too much attention on construction, product imitation, and the existence, size and number of equipment, and also neglected research and development as well as technological innovation; thus technological development lacked momentum.[202]

Mao Zedong had also realized this, thus in a speech in 1958, he said, "We are not good in heavy industry and in its design, construction and installment. Besides, we lack experience and have no experts. Since ministers are laymen, we can just copy foreign patterns without identifying them. What's more, we also need to break the bourgeois ideas of old Chinese experts by depending on Soviet experience and experts. We copy mechanically from the Soviet the designs which are proper in most situations, but in some are not."[203]

After the break in Sino-Soviet relations, Chinese industrial construction and technological development mainly depended on itself. Later on, on the one hand, China sought Western technology and tried to get rid of the problem of acquiring technology from a single source by contacting Japan and Western Europe; on the other hand, it

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[202] 张柏春、姚芳、张久春、蒋龙：苏联技术向中国的转移 1949-1966。济南：山东教育出版社。2004。Zhang,Baichun,*et al.*eds: Technology Transfer From the Soviet Union to PRC. Jinan: Shandong Education Press.2004:93-94.

[203] 毛泽东，在成都会议上的六次讲话，1958 年 3 月 10 日，毛泽东思想万岁（1958—1959）28。Mao Zedong,The 6th speech on the Chengdu conference, March 10, 1958, Long live the great Mao Zedong's thought.(1958-1959).

independently researched and developed major products, including the "nine equipments"[204] and improved its capacity for technological innovation. China started to engage in independently exploring the development of major products. In the 1960s, Chinese engineers made new attempts at heavy machinery manufacturing.

The idea of building a hydraulic press of ten thousand tons was suggested by Shen Hong (沈鸿), an engineer, to Chairman Mao. It was doubted by many people who argued that if we want to build a hydraulic press of ten thousand tons, we needed to have one first. That is to say, we should import a hydraulic press of ten thousand tons and construct a heavy machinery factory of ten thousand tons to manufacture the needed large forgings if we want to build it ourselves. Moreover, it was impossible to import one since there were few hydraulic presses of ten thousand tons in the world.

Chairman Mao approved the suggestion by delegating Shen Hong as the general designer and Lin Zongtang (林宗棠)，who was transferred from the Machinery Bureau of the State Economic Commission, as vice general designer.[205]

Because of the political importance of the project, it was full of excellent engineers in the group - Xu Xiwen (徐希文) was employed as the leader of the technology group in the design office.[206] Shao Bingjun (邵炳钧) who was the deputy chief engineer of the

[204] They are: 1. 30,000 tons forging hydraulic press, equipment; 2. 12,500 tons horizontal extrusion hydraulic press; 3. 2800 mm hot-rolled aluminum rolling mill; 4. Roll width 2800 mm cold-rolled aluminum sheet mill; 5. 2-80 mm diameter steel cold rolling mill; 6. 80-200 mm diameter steel cold rolling mill. 7. 2300 mm alloy sheet rolling mill. 8. 10,000 tons of hydraulic machines ; 9. 700 mm strip mill rollers. see: 中华人民共和国国家经济贸易委员会编：中国工业五十年：1949-1999，第九卷。北京：中国经济出版社, 2000。People's Republic of China State Economic and Trade Commission ed.: China Industry (1949-1999) Vol.9. Beijing: China Economic Publishing House, 2000:828.

[205] Lin graduated from the department of mechanical engineering of Tsinghua University in 1949, had initiated technical improvement activities like metal cutting with higher speeds during his stay in northeast China, and later on, he had acted as the first vice plant manager of Shenyang No. 1 Plant of Machine Tools, deputy director of the State Economic Commission, and deputy section chief of the marine engine section of design department in Jiangnan factory.

[206] After graduating from Dalian Institute of Engineering, Xu furthered his study in the postgraduate class opened by Soviet professors in Shanghai Jiaotong University. He had taken part in the task of repairing Soviet West Billy Treff of ten thousand tons.

Jiangnan factory had also joined in the task for a short time. To support the task, many engineers and technicians from other factories like the Jiangnan factory and Shanghai Mechanical and Electrical Design Institute were transferred to take part in the task. It was a group full of vigor, since most group members were of no more than 30 years old. For example, 32 year old Lin Zongtang played the leading role alongside 27 year-old Xu Xiwen - young, passionate, hardworking and bold.[207]

Coordinating with all factories, with Jiangnan shipyard at the center, they finished the investigation, design, testing and manufacture of the hydraulic press in four years. Engineers applied methods like imitation, modeling and experimenting comprehensively, and effectively integrated high, medium and low levels of technology. In the process of design, they learned from some foreign structural designs. However, since Shanghai lacked the technical capacity for heavy casting and forging, large machining and big lifting, Chinese engineers adopted a labor-intensive method in their manufacturing technique: They employed all-welded construction with six cylinders and four pillars, joined small ones with big ones through electronic slag welding to make up the insufficient capacity in casting, processed big pieces by use of several small mobile machine tools, and used hundreds of sleepers and dozens of oil jacks to lift and rotate components like bottom-end rails to make up for the lack of large-scale heavy lifts.[208]

In 1962, the installed hydraulic forging press of 12,000 tons succeeded in a test run in Shanghai Heavy Machines Plant. Undoubtedly, its design and construction had shortcomings. For example, electronic slag welding and "ants gnawing bones"[209] using to

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207 孙烈：中国走出自制重大技术装备困境的一次尝试—上海 1.2 万吨锻造水压机的设计与制造。自然科学史研究。2011 第 3 期第 30 卷：366-382。Sun,Lie：A Case Study on China's Self-made Major Technical Equipment: The Design and Manufacturing of Shanghai's120MN Forging Hydraulic Press. Studies in the History of Natural Sciences Vol.30 No.3(2011):366-382.

208 赤木昭夫，佐藤森彦：中国の技術創造Chūgoku no gijutsu sozō，中央公论社，1975。Akagi Akio & Kimihiko Sato: Technology creation in China. Chuokoron-Shinsha, Inc.1975.

209 It was a special method, which boomed in machine building industry during the Great Leap Forward. It was related some cold and hot working procedures. Ants represent small mobile and building block motion tools; and the bones were large work pieces that processed by foundry, forging, or weld. As a kind of substitutive technology, the method relied heavily on personal experience of mechanics rather than advanced machines.

solve the problem of stress concentration were of low efficiency, and its economical efficiency was also low. However, these were not the most outstanding and urgent problems. The primary goal of building a hydraulic press of ten thousand tons independently was to solve the problem that we did not own one. Because of this, the big machine in Shanghai was regarded as a prominent achievement of Chinese engineers in the equipment manufacturing industry and even in the history of Chinese industrial development. During the second and third Five-Year Plans, to meet the needs of construction of basic industries and the national defense industry, China developed a set of equipment for the production line of train wheel tires, two free hydraulic forging presses of ten thousand tons, and nine big equipments independently. These heavy machinery products were of a higher level of technology and were difficult to manufacture. Due to the close coordination of various departments, proper and feasible technical routes in design and manufacturing, and attention of state leaders, the development of these major projects all succeeded. These major products not only made up for many gaps and shortcomings in large-scale equipment in China, but also improved the scientific research and production capacity in the heavy machinery industry. At that period of time, the status of engineers experienced ups and downs due to changing politics and several periods of economic depression in China. These heavy machinery products were valuable achievements of Chinese engineers, made after overcoming difficulties and sacrificing personal gains in a special time.

In the late 1960s, however, this incentive power gradually faded away. In the 1950s, leading cadres and staff of enterprises displayed rousing zeal under the long-term education emphasis on selflessness, and people's positive vision of communism further motivated their enthusiasm and energy to struggle for the system
. However, for spiritual enthusiasm to replace material interests was a temporary state of affairs. With the development of communist construction in China, industrialization at the expense of people' interests resulted in the decrease of people's enthusiasm for production, causing the effective systems of the early days following the founding of the nation to

gradually lose their source of power in the late 1960s. In the 1960s, the respected magazine Red Flag published several articles to give suggestions to social science workers, including the idea that it was not necessary for them to concentrate on problems directly related to political and class struggle. With the call giving rise to some unprecedented discussions, especially regarding the economy, engineers and economists put forward suggestions similar those of Soviet reformist economists. In economics, like their Soviet counterparts, they advocated a pragmatic attitude instead of an adherence to empty theory, and they strongly argued for profit and efficiency, instead of politics, as the basis for investment. Obviously, leaders believed that political activities would be more effective, thus they hoped to rouse people's enthusiasm for revolution and weaken their ambition for material benefit through another revolution. However, the development of the Cultural Revolution did not achieve what they had expected; instead, it resulted in engineers and technical cadres, the subjects of technical innovation and improvement, in industrialization, suffering severe suppression. Nevertheless, since the engineering industry received great attention in the third and fourth Five-Year Plans, the shortage of engineers and the nation's major investment plan gave rise to the unbalance between advanced equipment and backwards technology.

From the results, we can know that the development of advanced precision products was slow. Taking numerical control machine tools as an example, China started to develop them since 1958 and they were put on the shelf in the 1960s. This was just several years later than in America and Japan, but development stagnated. In 1973, the country organized a campaign that lasted for three years to tackle key problems in producing numerical control machine tools. After the campaign, the number of products increased from eight in 1973 to 46 in 1975, but they did not become popular.

Another example was hydraulic technology, first used in the machine tool industry in 1975, adopted by tractors in 1958, and by 1962 used in engineering machinery. In the 1970s, the economic problem facing China was the severe shortage of energy and raw materials because of the relatively large expansion of machining. In industrial technology, there was a wide gap between China and Western countries in automatic mass technological production and petrochemical engineering. In February 1972, the visit of American president Nixon to China improved the international environment for China and brought an opportunity to enlarge its introduction of western technology. At the beginning of 1973, the country decided to introduce complete equipments and machines worth 4.3 billion Dollars from 1973-1977. By the end of 1977, the volume of the transaction was about 3.5 billion Dollars. The country mainly brought in products that belonged to weak links in production and technology, for example, in petroleum and chemistry engineering. The core technology imports were hardware instead of software. The country ordered a number of advanced large equipment that were beyond the capacity of Chinese engineers. Automated technology, controlled by advanced computers, was brought in from Western countries, which required management by people with high-level professional ability. In China, however, managers, including workers along with engineers, were gathered to make decisions. The duty and authority of managers and engineers could not be distinguished. On the other hand, the ultra-left trend of thought and xenophobia of the Culture Revolution gave rise to an overly cautious approach towards foreign technical advisors. Fearing that frequent contact with foreign experts would result in political suppression, Chinese engineers' lack of discussion during the process of importing technology, and feasible investigation and communication about problems in construction resulted in unnecessary troubles in construction, a process termed "passive technology transfer" by George Holliday.[210]

Besides the introduction of complete equipment, the government also constantly delegated power to lower authorities, delegating enterprises under central management to the provinces, then to cities, regions and counties. Many communities established machinery works, forming a situation that all areas had machinery works, from

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[210] Hardt,John P. & D.George: Holliday: Technology Transfer and Change in the Soviet Economic System. Technology and Communist Culture: The Socio-Cultural Impact of Technology under Socialism, ed. Frederic J.Fleron, Jr. New York: Praeger Publishers,1977:189-192.

departmental and provincial levels to county and community levels. The biggest obstacle in front of local middle and small-sized enterprises was the shortage of technicians and skilled workers. According to the report of an American inspection team on Chinese small-sized industries, the average proportion of technicians in most enterprises they visited was only 1-2%, and most of them had not received On the Job Training (OJT) or professional education. In order to make sure of the supply, local governments had to lower technical standards and adopted a protection policy of forbidding nonlocal products from entering into the local market. In this way, outdated techniques were impossible to weed out. Therefore, engineers had to focus on tackling problems in production and construction instead of on digesting introduced technology and on innovation.

The situation changed with the reforms that the CCP made during the 1980s. In 1982, the Central Committee of the CCP and the State Council issued the "Decisions on All-Round Reorganization of State Industrial Enterprises" which marked the beginning of a comprehensive reorganization of these enterprises, engineering industries started to explore reforming management systems. China's policy guidance focused on applying and commercializing technology and improving enterprises' flexibility regarding technical progress. The main jobs included expanding the decision-making power of enterprises and decreasing mandatory production planning in engineering industries. By 1987, only three kinds of products were mandatory; namely, automobiles, power generation equipments and electrical wires. Enterprises gradually readjusted their product mix according to market requirements by integrating into markets. Meanwhile, technical reforms carried out by enterprises resulted in the adjustment of management and personnel systems, quite a few factory directors and chief engineers with more than a junior college educational background, knowledge of technology and ability in management sprang up.

Chinese mechanical engineers who were put in important positions were met with challenges in two aspects:

1. Basic economics and management theories were emphasized. The advancement of

industrial and engineering technology not only meant that they could create more and better products and services, but also that they could create more and better products and services with less resources. As a means of developing productivity, technology had obvious and outstanding economic effects. In the 1980s, after enterprises gradually changed their systems, administrative instructions from the government were gradually replaced by market requirements; and the government abolished step by step the policy of controlling enterprises' procurement and distribution of products, thus, the practice of neglecting markets and costs was no longer appropriate. Lacking administrators in enterprises, the government put engineers with higher education backgrounds and a grasp of technology in management positions. Therefore, the status and function of management became more and more important in mechanical engineering. Since organization and management were not regarded as technology, they had been a long-term weakness for mechanical engineers.

2. It was extremely urgent to update old knowledge. In the 1980s, most engineers in enterprises had graduated from junior colleges or technical secondary schools during the 1950s to the 1960s, and had rich practical experience after staying for one or two decades in enterprises. After the 10-year long Cultural Revolution, however, engineers devoted most of their time to the revolution, due to the leadership's contempt for technology. Moreover, with the rapid development of modern science and technology, the cycle of updating knowledge was shortened and the speed of updating advanced disciplinary knowledge was even faster; for example, materials used by mechanical engineers expanded rapidly from steel to light metals, non-metals, high polymer materials, semiconductor materials, rare materials and nanometer materials. The method of creating new molecular materials made it possible to have different interior materials in the same component, which brought huge challenges for engineers. Undoubtedly, mechanical engineers needed to refresh their knowledge. Quite a few engineers felt that the technology and knowledge they obtained lagged behind. From 1984-1986, China introduced a large number of mainly

micro-computers, but most of them remained in warehouses since they could not be adapted to by engineers, which reflected the situation of Chinese engineers in accepting new technologies and methods.

4.1.3 Tertiary industry engineers: Working around political tasks

Since the situation regarding the tertiary industry was relatively complex, we should have a more complicated analysis and division of it, including five sections, namely: The transportation industry, storage and postage, education, health, social security and social welfare, scientific research, technical services, and geological prospecting. From the distribution of engineers shown in the fourth section of Chapter 2, we can see that the proportion of health workers was second to the two basic industries - manufacturing and agriculture. In this chapter, we will focus on the introduction of engineers in healthcare, because it had its own characteristics according to the national conditions. In the latter half of the 20th century, the international community attached more and more attention to family planning and reproductive health focusing on controlling population size and improving living standards, and advocated the idea of people first, informed choice and high-quality service. As a populous country among developing countries, the issue of population has been a theme that cannot be ignored in the economic development of China. How to control population size scientifically and improve quality of life of the population became a key issue. Chinese engineers not only realized the task of industrialization and agricultural modernization, but also assumed the bigger social responsibility and political task compared with their counterparts in other countries in public services in health care. In this chapter, we will focus on the vocational status of engineers who have contributed to public services.

Ma Yinchu (马寅初), an economist and demographer, put forward the theory of population control in the mid-1950s, which caused a furor in domestic academic circles and wider society.[211] However, due to insufficient research on the internal relations

[211] People's Daily. July 5th. 1957.

between population size and economic and social development as well as insufficient knowledge of the importance and effect of population, population control did not receive proper attention. On the contrary, the scientists and engineers who held related opinions were criticized during the Cultural Revolution. Since the 1970s, the issue of population received attention from party and government leaders again. In order to win theoretical support of the scientific community, Song Jian (宋健)[212], the vice-president and engineer from the 7th Department of Machinery in the early 1980s, conducted systematic quantitative research in population control from the aspect of theory and application. This research achieved optimal control in mathematical model, population index, dynamic analysis of the developing population, theory of stability, population prediction, population structure, the process of population development, predicted population development by use of the theory of system engineering and demographic data which could be obtained at that time, and put forward the theory of population control to guide the development of family planning.[213]

These theoretical achievements accelerated the perfection and implementation of China's policies regarding population and laid the theoretical foundation for the theory of population control. Later on, engineers and economists like Qian Xuesen (钱学森) and the economist Xu Dixin (许涤新) sent a letter to the State Council together, hoping to bring attention to the significance of the research. After winning the support of the government, scientific research in population control developed rapidly.[214]

With the establishment of the Science and Technology Institute of the State Family Planning Commission in September 1979, a relatively complete research and development

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212 Song studied at Harbin Institute of Technology, got his PhD degree of engineering in the former Soviet Moscow Bauman College. He served as director of the National Science and Technology Commission, he was the vice chairman of CPPCC National Committee, and he is also the member of Chinese Academy of Engineering and Chinese Academy of Sciences.

213 宋健、于景元：《人口控制论》。科学出版社，北京，1985。Song,Jian;Yu,Jingyuan: Population System Control. Beijing: Science Publishing house.1985:2.

214 孙沐寒：中国计划生育史稿。长春市：北方妇女儿童出版社 , 1987.Sun,Muhan: History of Chinese family planning.Changchun：Northern Women and Children Publishing House.1987:117.

system of family planning and reproductive health as well as a technical service network throughout urban and rural areas were improved gradually. Through the network, engineers developed and popularized a host of new-type medical tools, apparatus and fertility technologies. According to the actual demand of family planning, the overall design of the scientific and technological work of family planning placed emphasis on the overall strategic target of the national family planning, sound child rearing and reproductive health, focused on solving difficulties and urgent problems in the scientific and technological work of family planning, emphasized the industrialization of new technologies and the development and introduction of products, and realized the combination of popularization, monitoring and application so as to make the scientific and technological work drive the construction of basic technical service quality assurance system. Through policy-guide measures, fully absorbing advantages of central authorities, locals, armies, enterprises and other industries and assuming the task of technological development and services of family planning together, large-scale cooperation among departments and industries could thus be realized.[215]

Paying much attention to scientific research and the technical services of family planning, China had systematic planning and implementation. Major organs that took up scientific research of family planning included two key national laboratories, 27 national and provincial family planning research institutions, the Chinese Academy of Sciences, and scientific research institutions in higher schools as well. The country guided and organized various scientific and technical research and development institutions to develop new technologies and products according to the actual demands of family planning. Some of these which had proprietary intellectual property rights had international effects.

Family planning had a complete service system. The country had 2,457 country-level family-planning service stations, 38,629 county-level family-planning service stations, and over 40 enterprises that took part in family planning and the production of reproductive

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[215] 当代中国的计划生育事业编辑委员会编：当代中国的计划生育事业，北京：当代中国出版社。2009年9月。Contemporary China: The Family Planning Cause. Beijing: Contemporary China Publishing House.2009.9

health products. Moreover, achievements were made in prenatal diagnosis of congenital genetic diseases, reproductive health diagnosis and treatment, and treatment of infertility including test-tube baby technology.[216]

However, people had different opinions on the implementation of the engineering, and sanitation engineers reflected themselves in their attitudes to science, for example, in the 1980s scientific rationality was popularized, scholars who supported the "one child" policy wholly negated various social issues brought on by population control in the name of science, and argued that there would be no aging problems until 2030, which is nowadays considered a misunderstanding of the science. The scientific and technical work of family planning undoubtedly had a significant effect in the transformation of population reproduction and decreased the economic and social pressure caused by rapid population growth. Family planning played an important role in accelerating China's economic development, improving people's living standard and the overall national strength, and in relieving the heavy pressure of population on economy, the society, resources, and environment. This was the reason why the book *Major Achievements of Engineering Technology in the 20th Century* (published in 2002) which was edited by the Chinese Academy of Engineering and academicians of Chinese Academy of Sciences put the engineering of family planning in 11th place.[217]

[216] 中国工程院常平主编：20世纪我国重大工程技术成就。广州：暨南大学出版社。2002:127-133。Chinese Academy of Engineering, Chang, Ping ed.: Major Achievements of Engineering Technology in the 20th century. Guangzhou: Jinan University Press.2002:127-133.

[217] 中国工程院常平主编：20 世纪我国重大工程技术成就。广州：暨南大学出版社。2002:127-133。Chinese Academy of Engineering, Chang, Ping ed.: Major Achievements of Engineering Technology in the 20th century. Guangzhou: Jinan University Press.2002:127-133.

4.2 Careers and Opportunities

4.2.1 Lifetime employees in Danwei

Since the founding of the nation, the CCP supported technology through administrative organizations, including intervening in engineering through policy and supervising all policies related to the occupational benefits of engineering. In order to manage personnel under the public ownership system, the CCP reorganized and redistributed social resources through its administrative power on the basis of Danwei (the basic social unit, such as a research institute, a university department, and an enterprise), and offered staff an all-dimensional lifetime security to relieve their worries about work, life and family and to make them fully feel the superiority of the socialist system and the sense of pride and responsibility as masters of the country, which was the initial intention of the establishment of the Danwei system. As the basic unit of the nation's control system, Danwei was not only the final executor of national policy but also a support for the whole political system and the final distributor of resources; this resulted in the country's compulsive extraction of resources and Danwei's dependency on the country. Danwei's control of resource quantities and its administrative level and size relied on the supply and rule of administrative power. Meanwhile, as the main body of the national control system, Danwei had the function of controlling individuals and realizing social integration in spite of its dependence on the supply of national resources. To be more specific, Danwei provided individuals with resources for their survival and development, thus they did not need to rely on their efforts or supplies of society. Once a person entered a Danwei, it meant that he/she would obtain a sufficient and lasting guarantee. Individuals who broke away from a Danwei had difficulties in seeking greater development opportunities and a sufficient guarantee of resources. Danwei was decisive for individuals. From the aspect of individual value, it was the only channel for individuals' socialization.

After the three Great Reconstructions in the early years of new China, engineers were absorbed into Danwei as state cadres. Since engineering had become a nationalized occupation, the country had complete control over engineer self-employment and corresponding occupational policies did not exist. The country had also set up rules for admission and affected teaching contents that decided the occupational foundation and social activity space required by engineers through educational reforms. As was said in Chapter 3, ultra-narrow major-setting resulted in single career choice for engineers and the country's unified distribution of work meant engineering graduates had no choice in job selection. Furthermore, the country also confirmed engineers' status in the social distribution system through a series of laws and regulations, including the prohibition of self-employment, and pension and salary systems for engineers under the state-owned economy. The country controlled engineers' activities by monopolizing resources so as to make them obey Danwei. Engineers' social existence as individuals was replaced by the existence of units and labor unions, and engineers lost their independent ability as individuals. In addition, architectural engineers, who constituted the biggest group of freelancers in engineering groups, were traditionally also listed in national or local designing institutes. Like other occupations, jobs of lifelong tenure relieved engineers from the risk of unemployment. Qualifications and records of service in Danwei and length of service were major standards in assessing engineers. Although the improvement of individuals' professional skills was theoretically important, it was not regarded as major factor in aspects related to material gain and social position. According to a report about the conditions of scientists and engineers in 1990, among all respondents, 70% had worked in the present Danwei for over 20 years, 26% for 20-29 years, and 18% for over 30 years. In higher schools, the situation was even more serious, with 28% having stayed for over 30 years. In China, most engineers devoted their entire career to an institution.

Meanwhile, Danwei's absolute control over the engineers' working scope and working place created another approach for technology communication. For example, the fact that engineers trained technical workers in new technology plants was realized through their temporarily transfer from Danwei. Taking Daqing oilfield construction project as an example, when the oilfield was started in the late 1950s a large number of skilled workers and technicians were transferred from the old Yumen oilfield in Gansu Province besides the army of engineers. In the mid-1960s when Daqing oilfield was on track to work, it sent over 50,000 technicians and managers to start-up the Shengli oilfield in Shandong Province and the Dagang oilfield on the coast of the Bohai. In addition, in the mid-1960s when the Panzhihua iron and steel plant in Sichuan Province was started, all large iron and steel plants with Anshan iron and steel factory as the center provided not only machinery equipments, but also technicians and engineers. At the same time, when Hubei No.2 automobile factory was in its early days of establishment, dozens of large factories (with Changchun No.1 Auto Plant as the center) took a hand in helping it. Hubei No.2 Automobile Factory borrowed engineering and technical workers from Changchun No.1 Auto Plant for assistance in technology and personnel training. The two parties conducted a borrowing contract with an organizational relationship, with the wages and benefits of borrowed engineers remaining in the original Danwei.[218]

Although the part-time system of scientific and technical workers and the staff-employment system of enterprises was run on a trial basis in the 1980s, under the guidance of government institutional reform and the direction of enterprises' reforms, it was a good starting point for the marketization of engineers. However, due to the incompleteness of the system, employment was a mere formality, and the life-tenure system, which lacked competitive pressure, was still a mainstay of enterprises and units under collective ownership. To protect its technologies, a unit suppressed part-time professional technical workers. For example, a report published in the People's Daily on January 22 1987 read: "Technicians in the transportation department of Wuzhou, Guangxi were rewarded over RMB 600 by designing floating piers and boats for other plants in other provinces in part time. Meanwhile, local engineers were paid over RMB 2,000 by assuming the design of water projects in suburban countries in their spare time."[219] However, they were reported corruption by Danwei, where they worked, and were arrested

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[218] Technology cadres Regulations 1958.

[219] China Daily,1987.Jan 22.

after investigation.

Units controlled all resources used by people from the cradle to the grave, and the relationship between people and units was based around resource dependency. Under the system, if people could not get rid of their dependency on the monopolized resources of units, they had to give up their autonomy as individuals to pay the price for resource exchange.[220] On this occasion, it was easier for engineers who acquired relatively stable qualifications and human relations to break away from scientific spirit and accept administrative arrangements. To change the situation, the administrative style and approaches within and outside units was in urgent need of reform. It was noteworthy that with China's transformation to a market economy, many market and autonomous factors emerged in governance structure and power relations; thus, the dependency structure had subtly changed.[221]

4.2.2 Opportunities to move up

Administrative intervention became the fastest and most effective method to motivate engineering and technical workers' enthusiasm for technological improvements and innovation under the personnel system of uncompetitive units.

To enhance enterprises' motivation for technological innovation, the party adopted the measure of regarding enterprise workers with enthusiasm for technology as activists. During a time when the materialist-driven motivation was lacking, models set by units acted as an important means of guiding people. It was significant for activists, because it reflected the intention of China to create a new spirit functionally similar to entrepreneurial spirit whose importance to technological development in the capitalist

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[220] 李汉林：中国单位社会议论、思考与研究。上海：上海人民出版社。2004。Li,Hanlin, Thoughts on Chinese Work-unit society. Shanghai：Shanghai People's Publishing House.2009:40.

[221] National Science and Technology Commission Science and Technology Department, Science and Technology India：program approach in January 1973, cited from Research and Revolution:28.

system was well known to everyone.[222]

Many veteran workers were regarded as activists and were promoted to technicians or engineers. This action not only combined with the "mass line", but also relieved the shortage of engineering and technical workers in factories. Indeed, to meet China's need for technical personnel, the action had significant meaning. The promoted veteran workers had to have something in common: They should be reliable in politics, work hard, be skillful, be steadfast and earnest in their work, and have a long working history. Their experience was widely popularized in order to motivate all staff and technical cadres to join in technological improvement and innovation.

For achieving the aim of motivation, the regime enthusiastically promoted many activists and veteran workers to the position of engineers at expense of the college graduates. For example, in the Manchurian railway system alone in 1962 500 workers were reported to have been promoted to engineers or chief engineers.[223] In the Anshan iron and steel center, in 1960 300 veteran workers were reported to have become engineers or factory directors and 3,300 were promoted to technicians.[224] In the same year, several thousand graduates of part-time colleges were immediately appointed as chiefs of workshops or as engineers. In Shanghai alone, 1,000 became engineers. It is evident that Chinese policies made practical experience and political loyalty, rather than academic attainment, the criterion for promotion to the rank of engineer. The level of education is reflected remarkably in the leading personnel of industrial enterprises. During 1958-1960, estimated on the basis of scattered reports, around 10,000 technical workers rose to the rank of engineer, only 15 percent of the total number of graduates from the full-time colleges of engineering in this period and the number of worker-engineers rose steadily.[225]

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[222] Richard P. Suttmeier：Research and Revolution--Science Policy and Societal Change in China. Lexington Books.1974: 122.

[223] Zhongguo Xinwen, China News Service, January 9 1961:3.

[224] China News Service, February 11,1960:10.

[225] Chuyuan Cheng: Scientific and engineering manpower in communist china 1949-1963, Institute of Far Eastern Studies Seton Hall University, South Orange, New Jersey.1965:62.

Since the 1960s, a large number of engineering and technical graduates were distributed to enterprises; thus the shortage of technological personnel was relieved. However, policies were not readjusted in time. It was still easier for veteran workers than for recent college graduates to be promoted to engineers. A graduate from an engineering college, even after three to five years of experience in a factory, could be employed only as a technician. Few held the title of engineer. The CCP motivated grassroots workers' enthusiasm for production to the maximum degree through this. The regime, however, on the one hand had frustrated technical personnel with higher education degrees, and on the other hand had decreased the capacity and technical level of engineers. As Zhang Zhenzhong, president of McDonnell Douglas, said, "In China, making full use of talents is more important than cultivating talents. Unfortunately, personnel cultivated in the 1950-1960s lost their chance to display their capacity due to the internal friction of over ten years."[226]

4.3 Regulations

4.3.1 Professional titles and professional posts

In comparison to other countries, the engineering profession was not strongly regulated in China; it is unclear what kind of people could call themselves engineers. In the early days following the founding of the nation, learning from the Soviet management model, China listed technical workers in the management of "state cadres". Similar to party and government cadres, technical workers carried out the appointment system, and their technical position was related to wages and benefits and was enjoyed throughout their whole life. As a kind of professional technical workers, engineers were classified into several ranks. Each rank had strict requirements. Only when a person met the requirements could he/she be appointed by administrative organs. Ranks were in line with the wage

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[226] 樊相如：论工程师群体素质。科学学与科学技术管理。1989 年第 9 期。Fan,Xiangru: Qualities of engineers. Science of Science and Management of S.& T. Vol.10, 1989 No.9:42-43.

grading system. In the professional post and wage standards established in July 1952, the professional posts of technical workers in government organs included the posts of engineer, technician, assistant technician and intern. In the "Wage Standards of Personnel in Governmental Organs" formulated in 1956, professional posts of engineering technicians included chief engineer, assistant chief engineer, engineer, technician and assistant technician. At this stage, China implemented the system of a planned economy. The government carried out assessment management in state-owned enterprises or collectively-owned enterprises, while units decided engineers' professional posts and wages. Engineering was a profession that belonged to state cadres. The Qualification-Professional post-Wage management method basically adapted to the planned economy. In the beginning of the 1960s, due to economic difficulties, only professional titles of engineers were introduced, but they had nothing to do with salary.[227]

The professional title appointment system of engineers was stopped during the Cultural Revolution. The idea of "restoring professional titles and establishing the technical post responsibility system" was not put forward until 1977.[228] In 1979, the assessment of professional titles of section-level cadres and professional cadres was officially started. According to the spirit of professional titles put forward at the beginning of the 1960s, the professional appointment system carried out in the 1950s evolved into the professional evaluation system: Professional titles of engineers which were evaluated by experts only manifested the capacity and achievements of engineering technicians without job requirements and quantity limitation. According to the engineer system, the current professional title system graded engineers instead of types of engineers. In line with the ranks of engineering talents, namely, primary level, intermediate level and senior

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[227] 当代中国编辑部：当代中国的人事管理。北京：当代中国出版社。1994。Contemporary china Editorial: Contemporary China-Personnel Management. Beijing : Contemporary china Press.1994:3-15.

[228] 郭建荣：中国科学技术纪事（1949-1989）。北京：人民出版社。1990年。1977年9月《中共中央关于召开全国科学大会的通知》。Guo Jianrong: China's Science and Technology Chronicle (1949-1989). Beijing: People's Publishing House. 1990. September 1977, "Notice on holding a National Science Conference by the CCP Central Committee":159.

level, engineers included technicians, assistant engineers, engineers, senior engineers and senior engineers with professorships. Professional titles had no term, that is to say, once it was obtained, one could enjoy it for life. However, a professional post was different. In the "Regulations on Implementation of Professional Post Appointment System" issued by the State Council in February 1986, it was pointed out that the contents of the professional post appointment system specified that a professional post was a job with clear responsibilities, qualifications and terms, could be only undertaken by people with professional business and technological knowledge, and that it was different from academic and technical titles which could be owned for life once obtained. The establishment of the professional post appointment system required the setting up of professional working positions, making clear responsibilities and qualifications according to actual demands, determining the reasonable structural proportion of senior, intermediate and primary professional posts on the basis of fixed allocations, appointing qualified professional technicians evaluated by the evaluation committee of administrative organs, and paying salaries to engineers according to their professional posts during their tenure. The main goal of the reform was to separate professional title evaluation from professional post appointment system. However, due to the effect of traditional ideas and the shortage of related reforms, professional post and professional title had not been strictly distinguished yet in practice. Thus the professional post appointment system evolved into the professional title evaluation system.

4.3.2 Evaluation system

The failure to distinction between professional titles and professional posts in practice reflected itself in evaluation of subjects. China did not have a third party to evaluate professional qualifications of engineers, and the promotion and employment of professional posts was based on units. There was no unified standard to assess various engineers in the wider society and all industries. For example, in the management appointment process for technical cadres, one common problem was how to comprehensively evaluate the quality and capacity of engineers. Considering that the problem was complex and that many factors were involved, the method of qualitative description was always adopted; to be more specific, holding an assessment meeting joined by related leaders and experts to evaluate engineers, and then making a comment on their qualitative abilities.

Here is an example of a characteristic. "In the course of his work comrade Zhang showed himself to be a knowledgeable worker with initiative; he knows his work, is greatly interested in new technology, installation technology in particular, is persistent in carrying out measures of technology implementation, can be used in a leadership job as a chief engineer of the enterprise." It's very difficult from this characteristic to see whether Zhang was suitable for this job.[229] Was the engineer good or bad? How can we evaluate an engineer comprehensively in this fashion? In addition, due to factors such as educational degrees, the experience and professional ethics of the personnel taking part in the evaluation and that their assessments in each particular aspect were different. All these brought difficulties to comprehensive evaluation. Furthermore, professional criteria of engineers at different positions in enterprises and units were different, which gave rise to enterprises' doubt regarding the evaluation of engineers in different positions. We can only evaluate a factor according to evaluators' subjective opinions with obscure grades such as 'good' and 'bad'. For example, the science and technology committee of a unit held a evaluation meeting to examine the quality and capacity of the engineers of the unit, based on which to decide whether someone can be promoted so as to give suggestions about personnel appointment to leaders of the unit. For instance, he who was considered good can be conferred the professional title and be promoted, he who was regarded as good but not as good as the other could be promoted, a person who did not get a good evaluation could not be promoted, while he who got a bad evaluation would be dismissed. Thirty evaluators were involved in the process, including leaders of the unit, technicians and

[229] 工程师论坛编辑部，工程师素质与能。沈阳：辽宁科学技术出版社，1988。Engineers Forum editorial department, Quality and Ability of Engineers; Shenyang: Liaoning Science and Technology Press,1988:456.

general workers, and the evaluation covered the following five aspects; Basic theory, practical ability, self-learning ability, foreign language, occupational ethics and sense of responsibility. However, more investigations in the professional field were not undertaken. There was a lack of communication and competition among units of the same industry and in assessing criteria within the profession as well, thus we cannot see much comparison in professional skills of engineers of the same type.

Since the 1980s, engineers put forward their own reform plans regarding the evaluation method, based around their professional qualities. In the academic discussion of the quality and capacity of modern engineers, initiated by the engineer forum in 1988, many engineers who participated in the meeting discussed the model of evaluating the quality and capacity of engineers. For example, Zhang Guoting (张国亭), an engineer of the Zibo Machine Factory in Shandong believed that we could evaluate the capacity of engineers through a systematic engineering method, and came up with an evaluation model; Lü Lixin (吕立新), a senior engineer at the Beijing Research Institute of Chemical Industry in the Ministry of Chemical Industry put forward the idea of evaluating quality and capacity of engineers by use of the modern fuzzy mathematical method. However, they did not break with Danwei's limitations, during this engineer forum, the importance of engineering professional organization which could be the best way to solve the qualification problem of engineers was not mentioned. Then, we should ask, what did Chinese engineering organization do, what kind of engineering organization did Communist China have, what kind of work did they do after 1949?

Chapter 5 Organizations and pursuit of professional interests

Engineers, as an ocupational group, are diverse. They differ in their qualifications and social status, like academics, national public servants, and other people in positions in different technical sections. Diversification also means the diversification of benefits. Due to the diversity of engineers, occupational communities have a decisive effect on engineers' social status. So, a professional association that can represent the interests of engineers and pursue scientific and technological progress is essential, as a mutual engineering association able to maintain the standards of entry into the profession, encourage members to improve their skills in order to climb through a hierarchy of grades, promote specific training programmes for engineers, and to monitor the conduct of their members, applying disciplinary measures when necessary. They publish books and magazines, accelerate the development of professional disciplines and improve the professional standards of members by holding meetings, classes for further studies, lectures, and discussions. Many publications of the association became professionally renowned. Engineering association can be roughly classified into two categories: 1. Science and technology or professional associations; 2. Political associations related to profession.

However, the situation of associations became more complicated after the establishment of the PRC: the most important aspect in measuring an engineering association was not the professional but the political.

In the early years of the new nation, the CCP had a new idea about science and technology associations. The leaders of the new nation expected to establish new national, scientific and traditional organizations in line with their ideology; to be more specific, they desired to manage the intellectuals in science and technology by bringing them into a community.[230] After 1949, engineers were considered part of scientific and technological cadres to serve the government. The engineers became a constituent part of the Chinese

[230] 茅以升:中国工程师学会简史，文史资料选辑，第 100 辑，1985 年 1 月。Mao,Yisheng: A brief history of Chinese institute of engineers, Research Materials, The 100 series, January 1985:13.

national natural science association, as a part of mass organizations. Thus, the old Chinese Institute of Engineers was forced to end, as it was considered a scientific community of the "old" society. [231] Then, in the early days of 1958, the Chinese National Natural Science Association and the National Association for Scientific and Technological Popularization were combined due to their functional similarities, and given the name of Chinese Association for Science and Technology (CAST). Thus, a national mass organization of science and technology was formed.

The leaders of the CCP also decided to establish a comprehensive academy of science and technology as a national science and technology center after learning from the experiences of the Soviet Union. In 1955, after the Academy was formed, 233 elite Chinese scientists and engineers' were chosen as its members to constitute a committee.[232] Until then, the scientists and engineers' elites were under the national management of intellectuals, in essence.

In the late 1950s, the Chinese Academy of Sciences, an elite organization of engineers and scientists, and the mass scientific organization China Association for Science and Technology successfully brought engineers in different positions into a unified national scientific organization for management.

In this chapter, therefore, we must take note of these two major science and technology associations of the PRC. We will discuss some details about Chinese engineers taking part in organizing Chinese science and technology organizations from 1949 to the 1980s.

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[231] After the PRC was founded, the CCP called the everything that belongs to KMT period or Longer period "Old". For intense, Old society, Old China, Old customs. On contrary is "New". Wang, Yangzong, 王扬宗:1949一1950年的科代会：共和国科学事业的开篇，《科学文化评论》，2008年第2期。"1949-1950 scientific member congress: the opening of the Republic of science", "scientific and cultural Review",2nd Issue, 2008.

[232] 宋振能：中国科学院建立专门委员制度回顾。中国科技史料，1991。Song, Zhenneng: Review on the establishing of specialized committee system in CAS. Chinese Science and Technology Historical Material , 1991：4.

5.1 The tradition of engineering organizations

From the late 19^{th} to the early 20^{th} century, Chinese engineering endeavors began to be prosperous.[233] This was due to the following aspects: Firstly, after the founding of the Republic of China, the Nanjing provisional government set up the Ministry of Industry, issued decrees and policies to protect industries and commerce, and was encouraged to run industries. Thus, engineers were in an urgent need. Secondly, overseas students who were sent to study engineering technology in Europe, America and Japan in the late Qing Dynasty returned, and, in addition, the westernization movement, alongside military and industry schools, founded during the Hundred Days' Reform, cultivated a large number of engineering technicians. Due to the increasing number of engineering technicians, a special engineering group was needed in order to better consolidate engineers and develop engineering endeavors.

It was noteworthy that the motivation for associations' entry into China was not the need of domestic scientific and technological advance, as with most other associations, but intellectuals' desire to save the nation. During this time, science and technology associations were founded in succession, including the China Civil Engineering Society (1912), the Chinese Institute of Engineers (1912), the Chinese Medical Association (1915), the Science Society of China (1915), the Chinese Association of Agricultural Science Societies (1917), the Chinese Society of Forestry (1917), the Chinese Society of Mining (1919), the Chinese Astronomical Society (1922), the Chinese Meteorological Society (1924), the Chinese Society for Plant Pathology (1929), the Chinese Chemical Society (1932), the Chinese Physical Society (1932), the Aviation Engineering Society of China (1934, Hangzhou), the Chinese Institute of Electrical Engineers (1934) and the Chinese Mathematical Society (1935).

233 陈旭麓：近代中国社会的新陈代谢，上海：上海社会科学院出版社，2006 年 1 月。Chen, Xulu:"Modern Chinese Society of metabolism", Shanghai: Shanghai Academy of Social Sciences Publishing House, in January 2006:347.

By the end of 1948, the number of scientific and technical communities in China reached 136.[234] At that time, the number of comprehensive and professional scientific and technical communities in the liberated areas was over 30. Among them, the Chinese Institute of Engineers made up the biggest number. After the three societies were combined to form the Chinese Institute of Engineers on February 1 1913,[235] Chinese engineers returning from America established the Chinese Engineering Society in 1917. Later, on August 26 1931, the two sessions held an annual meeting in Nanking to approve the combination of the name of the Chinese Institute of Engineers. After that, the Chinese Institute of Engineers became the only comprehensive engineering academic body in China and thus the leader of engineering at that time. With a history spanning about 40 years, the Chinese Institute of Engineers ran through the whole era of the Republic of China. It was the biggest institute in terms of population and scale in the history of modern China. The institute was established by Chinese pioneering professional engineers such as railroad engineer Zhan Tianyou (詹天佑) and railroad engineer Yan Deqing (颜德庆) and was led by civil engineer Ling Hongxun (凌鸿勋) and bridge engineer Mao Yisheng (茅以升). It was a group constituted by modern professional engineers and played a role of civic leadership. The institute held meetings at regular intervals, issued publications, and opened branches continuously, which made a great contributions to the development of modern Chinese academic engineering and the progress of engineering technology.

The Chinese Institute of Engineers was tasked with promoting the development of China's industrialization. After its foundation, engineers conducted academic exchanges through engineering magazines as well as academies and annual meetings, and they pushed

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[234] This data is based on the book:何志平等主编：中国科学技术团体。上海：上海科学普及出版社，1990。中国科学技术协会组织宣传部。He, Zhiping ed.: Chinese scientific and technical community. Shanghai:. Shanghai Popular Science Press, 1990 China Ministry of Science and Technology Association organized propaganda.

[235] China engineers society (Guangdong), China Engineering Institute (Shanghai), Shanghai Railway Road work colleagues Masonic

for the development of engineering academic research. For example, they compiled and examined engineering terminology, promoted the formulation and implementation of industrial standards, and assisted the authorities in carrying out all works of engineering statistics and plans. For instance, they compiled the China Construction Item List(中国工程题名录) and the China Engineering Statistics.[236] They also provided references for the development of domestic engineering and gave directions for higher engineering education. The leaders of the Chinese Institute of Engineers were closely related to the government, which meant that most of the time the institute had a good partnership with the government. In addition, the institute was often invited by the government to carry out engineering and technological research and to popularize engineering knowledge. The government's approval of the occupational qualifications of engineers was also assisted by the Chinese Institute of Engineers. Moreover, in the leading group of the institute at different stages, most engineers held positions in important departments of the government. Even so, the institute still avoided becoming dependent on the government and continuously stressed its independence as an academic group while dealing with the government. As for the social functions of academic bodies, the institute even stood against the government, as proved when occupational groups petitioned for income tax in 1937.[237]

For engineers, the Chinese Institute of Engineers was not only a leader but also a servant; for all professional engineering societies, the institute was both an organizer and a cooperator, while, for the government, the institute could be a collaborator or an opponent.

[236] Members of CIE decided to write a more complete and accurate engineering statistics. Statistical content 14 industries includes railways, roads, water, construction, electricity, telecommunications, machinery, aviation and automatic machines, mining, metallurgy, chemical industry, education, commercial plants, miscellaneous. It became important reference book for engineers and technicians.

[237] In January 1937, Shanghai Bar Association, the China Institute of Architects, the Shanghai Medical Association, the National Federation of Physicians, China National Medical Association, the Chinese Institute of Engineers, National Medical Association, Shanghai, China National Medical Association, the Institute of Chartered Accountants of nine groups gather together to petition the Government for reconsider the new bill of income Tax. Source: Details about the income tax petition, Engineering Week, March 1937, Vol. 6, No.4.

The ultimate goal of the institute was to organize and lead engineers in carrying out academic and technological engineering research and to promote the development of modern engineering endeavors. The institute stopped operating in 1949 because of the civil war. Since quite a few engineers moved to Taiwan with the Kuomintang, the institute was reestablished in Taiwan in March 1951. It carried meetings actively, and up to this day, it still contributes to academic and technological engineering advances.

5.2 Professionalized political group: All-China Federation of Natural Science Societies

The Chinese Institute of Engineers emphasized itself a non-governmental professional in situation that was independent of the government but also a political occupational group. On the contrary, after the 1950s, all academic groups had a strong political nature and their political nature was more and more obvious from the All-China Federation of Natural Science Societies which replaced the CIE to the China Science and Technology Association.

5.2.1 Reasonable discussions on the All-China Federation of Natural Science Societies

At the beginning of the 1950s, several professional science and technology groups had little or no influence on the main current of China's advance in science and technology. Once the new nation was founded, these groups became parts of the Chinese National Natural Science Association. However, the function of the institute was doubted. Some relevant cadres believed that many operating departments could have direct cooperation with the research bodies of higher schools; thus the institute was useless. Many operating departments had the same doubt without actually knowing the institute. For example, to gain the support of the operating department, the chemical engineer Hou Debang (侯德榜) made requests to the department of industry several times directly and indirectly.

The department of industry also voiced its support and determined to let the bureau of chemical engineering cooperate with the institute, but the bureau still did not air its opinions and asked Hou "what exactly the institute was for".[238] Before the PRC, the institute could gather scattered engineers, because of their wide distribution. After the PRC was founded, the institute contributed very little in this respect since most engineering personnel in different disciplines was gathered in one or several operating departments and research institutes. Operating departments could exchange research and production experience for themselves. Once they had advanced experience, they would report to the public immediately, which was faster than the institute in efficiency.[239] Such thought was popular within the party.

In 1950, the minister of NPC Wu Yuzhang (吴玉章) put forward his ideas about scientific communities in the 10th standing committee of the preparatory scientific meeting. He argued that: 1. The main task of scientific communities was to assist national economic and cultural work; 2. scientific groups should draw close to related governments departments and become their auxiliary power; 3. the major organizational form of scientific communities in the future should be professional academic groups that were closely related to governmental organs; and 4. the scientists and engineers must be transformed into a new group from the old one.[240] In August 1950, the representative meeting of Chinese national natural science workers was officially held in Beijing where Chairman Mao met with representatives. At the meeting, the Chinese national cultural

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238 沈其益：中国科学技术协会。北京当代中国出版社。1994。Shen, Qiyi, China Science and Technology Association. Beijing Contemporary China Publishing House. 1994: 61.

239 何志平等主编：中国科学技术团体.上海：上海科学普及出版社,1990.中国科学技术协会组织宣传部.中国科学技术协会简史.1988:541。He, Zhiping *et al.* eds., Chinese scientific and technical community. Shanghai:. Shanghai Popular Science Press, 1990 China Ministry of Science and Technology Association organized propaganda .1988 Brief History of Chinese Science and Technology Association:541.

240 何志平等主编：中国科学技术团体.上海：上海科学普及出版社,1990.中国科学技术协会组织宣传部.中国科学技术协会简史.1988:541。He, Zhiping *et al.* eds., Chinese scientific and technical community. Shanghai:. Shanghai Popular Science Press, 1990 China Ministry of Science and Technology Association organized propaganda .1988 Brief History of Chinese Science and Technology Association: 541.

science association and the national association for scientific and technological popularization were founded with the geologist Li Siguang and the famous silviculturist Liang Xi as chairmen of the two organizations respectively and Wu as the honorary president of the two groups, under the control of the CCP.

However, the science and technology associations under the direct control of the party were very different to what engineers had imaged. Engineers thought that the new science and technology associations would not be too different from the original Chinese engineering groups in organizational form and enrollment standards. In fact, after the institute was forcibly to be recalled in 1950, science and technology associations gradually became close to mass organizations. Moreover, the democracy and freedom of academic groups expected by engineers could not be found in science and technology associations and their tendency to obey policy left engineers at a loss. Another thing that dissatisfied engineers was that the leadership was not very clear. All inner-party members held the opinion that science and technology associations were under the direction of the Chinese Academy of Sciences, but this was not confirmed. The uncertainty about tasks and operating methods gradually led many institutes into a standstill after their transformation. This brought the groups many problems regarding operating conditions, including the lacking of full-time cadres. Activities of the institutes were required to be reported to the government administration council for approval, and the time spent participating in activities had to be approved by units. The function of the institutes was only to call on and unify in politics and to show up in international activities; they were nominal. To solve the problem, director of People's Daily Fan Changjiang (范长江) and vice president of CAS Zhang Jiafu (张稼夫) chaired a meeting with the party committee of ACFNSS. The affirmation of the work of ACFNSS illustrated that it would assume significant tasks in the future, and it was expected to be "home of scientists" like the Soviet.[241]

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[241] 何志平等主编：中国科学技术团体.上海：上海科学普及出版社，1990。中国科学技术协会组织宣传部：中国科学技术协会简史。1988:541。He, Zhiping *et al.* eds., Chinese scientific and technical community. Shanghai:. Shanghai Popular Science Press, 1990 China Ministry of Science and Technology Association organized

From 1956, the role of professional science and technology groups seemed to have experienced significant changes. A typical activity at that time was holding meetings that became academic seminars whereby engineers from different units could affect and cooperate with each other. For example, the first annual academic conference of civil engineering was held in Wuhan in 1956. With the theme of combining the 156 major engineering projects assisted by the Soviet Union, an academic discussion on the construction of Wuhan Yangtze River Bridge was conducted. In the discussion, the civil engineer Wang Juqian (汪菊潜) delivered a report on the new constructing methods and Zhang Wei (张维) reported on the 5th meeting of the International Association for Bridge and Structural Engineering. Men from the National Construction Committee gave a speech in the meeting and conveyed the formulation of the 12-year scientific development plan. Under the advocacy of the engineers and scientists within the federation, starting from 1957, these professional academic groups became the channel between engineers and the authorities by participating in publishing academic documents and magazines.

5.2.2 The establishment of the China Science and Technology Association and its organizational form

However, the favorable situation did not last long. In 1956, the party central committee decided to march into science and strengthened its leadership on the ACFNSS and the National Association for Scientific and Technological Popularization. Meanwhile, due to the effect of the Great Leap Forward, parts of the work of the ACFNSS and the National Association for Scientific and Technological Popularization overlapped. In this environment, the work of the ACFNSS was similar to that of the National Association for Scientific and Technological Popularization. In addition, the associations that were improper to join in a mass organization were forced to be canceled such as the Society of aircraft engineering. The Central Committee of the CCP believed that as scientific mass organizations, the work of the ACFNSS and the National Association for Scientific and

propaganda .1988 Brief History of Chinese Science and Technology Association:539.

Technological Popularization which was specialized in scientific improvement and scientific popularization respectively had lagged behind the need of the Great Leap Forward.[242] Under these conditions, the ACFNSS popularized science among workers and peasants. On the other hand, the National Association for Scientific and Technological Popularization carried out a large amount of scientific research. The two organizations had joined together in practical work. On September 1958, under the approval of the Party Central Committee, the ACFNSS and the National Association for Scientific and Technological Popularization were merged and officially became a unified organization of scientific and technical workers - the China Association for Science and Technology (CAST).

CAST considered itself, in its association charter, a unified organization of all kinds of scientific and technical workers under the leadership of the CCP. According to the decision to establish the association, it was divided into national professional societies, special committees and local branches and committees. From the aspect of the society that CAST belonged to, it was involved in science, engineering, agriculture, medicine and inter-disciplines in national societies, provincial-level societies, local societies and county-level societies. The organizational system ran across most natural sciences and industries, it was a network-based organizational system with large coverage; meanwhile, special committees handled scientific popularization, inventions and patents, technology and occupations, as well as standards and scientific labor.

CAST was directly subordinate to the party central committee and was led by the secretariat of the central committee. A leader from the political bureau of the central committee was in charge of the work of the association standing for the party central committee; a leader of the State Council dealt with the connection work of the association; and the secretariat of the central committee received work reports from the association each year. CAST carried out the national congress system (once every five years), the

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[242] 沈其益：中国科学技术协会。北京：当代中国出版社。1994：57。Shen,Qiyi,China Science and Technology Association. Beijing: Contemporary China Publishing House. 1994:57.

national committee system (once a year) and the standing committee system (once every quarter). The standing committee set up 14 special committees including the special committee for academic exchange and association development and the special committee for science and technology popularization to assist in examining great events which needed the approval of the standing committee. The standing committee set up a secretariat whose work was to conduct daily works of CAST under the leadership of the standing committee.

During the reestablishment of the Association, a group of senior engineers held important positions in the association. Since the 1950s, CAST has held seven national congresses with geological engineer Li Siguang (李四光), astro-engineer Qian Xuesen (钱学森) and nuclear engineer Zhu Guangya (朱光亚) as the chairman of the 1,3,4th congresses respectively. Bridge engineer Mao Yisheng, a member of the early engineer association, was selected as the deputy chairman and honorary president of the second term of CAST, the chairman of the Beijing Association for Science and Technology, a committee member of the technology division of the China Academy of Science, and the third president of the China civil engineering society

All professional associations carried out the affiliation system. Besides being a part of CAST, the associations received the operational leadership of CAST. Meanwhile, they had to be affiliated with an industrial department or a scientific and technological unit, and the administrative bodies of the associations were guided and supported by the units they were affiliated to. The implementation of the affiliation system under the leadership of CAST was to strengthen the party's guidance over academic groups, to promote the combination of the associations and other relevant operating and industrial departments, and to gain support from the units of labor and finance. Since the associations were mainly responsible for the units they belonged to, they lacked the idea of membership service. At that time, industrial departments founded national engineering associations. Generally speaking, each ministry or commission had a corresponding society, for example, the architectural society, the machinery society, the textile engineering society and the institute for light industry. It is noteworthy that there were very few industrial associations at that time. [243]

In the terms of membership, before 1949, all societies had specific stipulations on membership according to their conditions. For example, members of the Yan'an academy of natural sciences had to be scholars of natural sciences with a of junior college or higher educational background at home or abroad, people with certain theoretical knowledge and working experience, and people who had contributed to natural sciences. The change of science and technology groups in nature and status also gave rise to a change in association members. The common criteria for membership was that members must have graduated or have reached an academic level equal to undergraduates from universities, have a working experience of over two years and have some scientific talent. After the establishment of CAST, however, although the China association of scientific workers was established with the goal of building a united front, it had a wide coverage, including researchers in academic organs as well as mentors, planners and executors in all production departments. Under the effect of the "left" route, some associations started absorbing in some talents in technical improvement. There was no limit between members of CAST and that of the associations. All workers, farmers and intellectuals who advocated for the leadership of the CCP and socialism and contributed to scientific inventions or technical innovations could file applications to be members of CAST after they were approved by primary-level organizations of the association in local areas or units regardless of their educational background.[244] By 1959, the number of the members was 20 million, making up about 3% of the total population. In 1961, CAST held a national working conference in Beijing, where Zhou Yang (周扬), then the deputy minister of the Propaganda Department of the Central Committee of the CCP, put forward his opinions about the membership of the association. He believed that the association did need members, but there must be certain

[243] 沈其益：中国科学技术协会。北京当代中国出版社。1994。Shen,Qiyi: China Science and Technology Association. Beijing Contemporary China Publishing House. 1994:75.

[244] 沈其益：中国科学技术协会。北京当代中国出版社。1994。Shen,Qiyi: China Science and Technology Association. Beijing Contemporary China Publishing House. 1994:61.

standards, and the number of members at a national level must be known. He said there was no need for too many members and that there must be requirements for national association members. Members must have certain knowledge, a certain job, and certain contributions. Only when making the entry into a national association as a kind of honor can it be a measure of the scientific level of a country.[245] However, "certain knowledge", "certain job" and "certain contributions" were not specific, which weakened the profesional and authoritative of CAST as a national top science and technology association.

5.2.3 Major activities

After the foundation of CAST, its subordinated professional associations were academic mass groups in nature. They were efficient organizations which unified scientific workers and improved their thought and professional skills through mass academic activities, a mass foundation and the assistance of national scientific research organs and operating departments, and helpful organization in socialist construction. The nature of scientific and technical communities like the national association had permanently changed. They were no longer independent mass organizations but organizations carrying out professional scientific and technological activities under the leadership and as part of the China Science and Technology Association.

The tendency of CAST whose goal was to serve to social reform of becoming the "tool" of CCP government was more and more obvious. On the one hand, as a part of the planned economic system, it participated in national scientific planning and the formulation of Five-Year Plans; on the other hand, in all special committees of the association, the inner-party power which represented the interest of national economy has been the leader. In September 1958, the All-China Federation of National Natural Societies and the National Association for Scientific and Technological Popularization

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[245] 韩晋芳：科技工作者：科技社团成员研究。学会， 2012 年第 4 期总第 281 期。Han, Jingfang: Research on Scientific and Technical Workers: the Member of Sci-tech Associations. No.4, 2012(sum No.281):12-15.

were merged, becoming CAST with the geological engineer Li Siguang as the first chairman. During the following ten years, CAST, a federation of scientific and technical workers, including engineering organizations, became a mass organization that cooperated with technical workers and intellectuals under the socialist system. It required its members to contribute to the scientific and technological policies of the CCP. Meanwhile, it also proposed overcoming the tendency to administration and correcting the relation between State organs and associations from the viewpoint of academic democracy, thus unifying its responsibility for the party and government leaders and scientific and technical workers.

However, the association spirit of "academic communication" and "social service" advocated by engineers did not fully come into play after CAST was founded.

At that stage, the specific work of CAST was not very clear. Besides formulating specific rules for the association, most works of the association regarded completing the system of local associations for science and technology, cultivate active workers and popularizing science. What was worthy of note was that in 1961, the "14 articles of scientific work" formulated against the Great Leap Forward included one article which put forward a slogan arguing that the academic world needed all schools of thought to contend for attention and all flowers to bloom together. Inspired engineers actively participated in activities of CAST again and put forward some requests, including the hope that association activities could be listed in working time, the issue of layering scientific and technical workers within the association, and the coordination of full-time cadres and part-time cadres. However, with the advent of the Cultural Revolution, these suggestions were criticized as anti-authoritarian or anti-revolutionary. Moreover, the China science and technology Association and all associations were forced to suspend and were named "revisionist Petofi Circles" by radicals.[246]

The first significant transformation of the scientific and technological policies of the CCP, during the third plenary session of the 11th national congress of the CCP in

[246] 沈其益：中国科学技术协会。北京当代中国出版社。1994：86.Shen,Qiyi: China Science and Technology Association. Beijing Contemporary China Publishing House. 1994:86.

December 1978 opened a new period of reform and 'opening up' the nation turned to promoting key technologies and quickening scientific progress from the line of heavy industry. In early 1977, when Qian Xuesen met with Zhou Peiyuan, they discussed strengthening CAST and the associations as bridges for scientific and technical workers from different departments to exchange ideas. Moreover, they sent brief reports to Deng Xiaoping, which let the party central committee know the opinions of the several famous science and technology experts on the construction of CAST and the associations. The organizations and activities of CAST were gradually recovered. The transformation of the technical and political line within the CCP had improved the status of all engineer associations. In February 1979, the ministry of finance opened an account for CAST by unifying its undertaking expenditures and external affairs. In May of the same year, the State Development Planning Commission approved CAST to open an account for capital construction, goods and materials, and foreign exchange.

Furthermore, the range of academic activities was more and more widened. The government transferred some functions appropriate for scientific and technical groups to them by means of request or guiding. The so-called 'request and guiding' was designed to encourage science and engineering associations to complete and recover their functions through measures like reform through documents, requirements and stipulations, thus realizing the transformation of governmental functions, such as educational certification, training, qualification authentication and talent evaluation. It is noteworthy that the transformation of governmental functions required responsible scientific associations to complete and adjust their functions, thus having a significant effect on the perfection of scientific and technological associations. For example, the Chinese Meteorological Society undertook the work of assessing professional aptitudes; the Chinese Society of Naval Architects and Marine Engineers assumed the task of strategic research into national ministries and commissions; the Chinese Hydraulic Engineering Society took over the function of evaluation of water conservancy talents, further education and the standardization of water conservancy; the Chinese Society for Measurement and the

Chinese Medical Association undertook the function of technical evaluation from the government; and the Chinese Mechanical Engineering Society, the Chemical Industry and Engineering Society of China and the China Computer Federation assumed the function of educational certification.

It is worth mentioning that after the reform and the opening-up period, scientific and technological consultation of CAST developed. In March 1980, CAST held the second congress, to make scientific and technological consultation as one of its major functions. In February 1981, CAST issued the "Notice on Associations and Local Associations for Science and Technology Establishing Agencies for Scientific and Technological Consultation" which required scientific and technological associations and local areas to build agencies for Scientific and Technological Consultation, as well as play a large advantages of CAST which includes making use of a wider variety of talents, cross-sectoral advantages, mobilize and organize scientific and technical personnel, technical consulting services. For example, in 1978 when the Bao Steel plan was started, the Bao Steel consultative committee founded by the Shanghai Association for Science and Technology, constituted of 30 specialists from 19 fields including mechanics, machinery, electrical machine, civil engineering, construction and steelmaking with civil engineer Li Guohao (李国豪) as the head adviser, and it played an important role in participating in discussions on the major policies of Bao Steel, including organizing 80 seminars and proposing 56 major suggestions.

On February 4 1982, the Ministry of Finance of the PRC and CAST issued the document 024, the "Interim Provisions on Charges of Scientific and the Technological Consultation of Associations for Science and Technology and Academic Bodies They Belong" to which stipulated the standards for charging of scientific and technological consultation. It was the first time that the value of science and technology and the value of engineers were affirmed in policy documents, something that greatly mobilized the enthusiasm of engineers and technical workers. Engineers finally favored associations for science and technology.

The academic function and the social service function of associations was fully developed after the 1980s, but the relation between CAST and subsidiary specialized professional institutions, as well as the distribution of rights and obligations, were not clear enough. The institutions are the affiliates of state organs, the autonomy by themselves is still doubtable. These problems meant engineers had to go on fighting for a long time in order to gain a comfortable, free and equal academic environment as well as to activate academic ideas and inspire academic spirits.

5.3 The Science and Engineering Academies

5.3.1 The internal organization of the Chinese Academy of Sciences

The Chinese Academy of Sciences, founded in 1949 the same year as the PRC, attempted to use science to speed up technological, economic, and defense-related development, as well as the entire process of modernization.

At the end of the Civil War in 1949, the CCP Central Committee considered establishing a unified Academy of Sciences as the highest academic institution, which historian and man of letters Guo Moruo (郭沫若) would be responsible for.[247] In mid-June, the Central Committee decided to assign the Propaganda Minister, Lu Dingyi (陆定一), to take full charge of preparation and establishment of the Chinese Academy of Sciences, chemist Yun Zijiang (恽子强), and psychologist Ding Zan (丁瓒) to assist Lu's work. physicist Qian Sanqiang (钱三强) and botanist Huang Zongzhen (黄宗甄) also participated in the course.[248] As can be seen from the personnel list, most of them were from the Party but the participation of elites in science and engineering was also actively involved. The deployment procedure for members of the Academy was quite

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[247] 樊洪业：中国科学院编年史（1949—1999）。上海科技教育出版社，1999：1。Fan, Hongye: Chinese Academy of Chronicles (1949-1999), Shanghai: Science and Technology Education Press, 1999: 1.

[248] 樊洪业，王德禄，尉红宁：黄宗甄访谈录。中国科技史料，第 21 卷，2000 年第四期。Fan Hongye, Wang Delu,Wei Hongning: An Interview with Huang Zongzhen, China Historical Materials of Science and Technology.Vol.21 No.4 2000: 316-323.

straightforward. First select consisted of 35 scientists from Academia Sinica as judges. The new group of judges then selected new members of different disciplines into the Academy based on their scientific achievements. On November 1, 1949, Chinese Academy of Sciences was officially founded as a government department under the Government Administration Council (the predecessor of the State Council). Like the Soviet Union, the CAS practiced double leadership, in which administrative and political management were from the Science & Technology Secretary of the Secretariat and the academic committees affiliated with the CAS's various organizations. They maybe had received a science and technology training, but none of these Party members were outstanding scientists or engineers, apart from only a few exceptions.

At the beginning of the new regime, the CAS mainly performed two functions. First, it had to be an institute actively engaged in scientific and technological research and committed to achieving national economic development objectives and enhancing its military capabilities. Second, as a government department, the Academy also has an administrative function and was responsible for all the affairs of natural and social sciences.[249] Thus, the CAS was both an academic and research institution and organization and a government department, which was quite rare in the establishment and development history of national academies all over the world.[250] Excessive administrative affairs had occupied Director Scientists in the CAS so much that they were almost parted from scientific research. At the end of 1949, Qian Sanqiang wrote a the letter to his teacher Irène Joliot-Curie about his concerns and ambivalence about being busy with administrative work while parting from field research. "For a while I was wondering whether I could go back to my research work. However, on the other hand, I know that people's victory is never an easy course. For the ultimate victory, everyone has a responsibility to contribute

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[249] 薛攀皋：中国科学院然科学史研究所院史研究室，薛攀皋文集。 2008。Xue,Pangao: Research on the history of Chinese Academy of Sciences Institute, Pangao Xue collected works.2008. Unpublished Monthly Review, November 1951: 153.

[250] 薛攀皋：中国科学院然科学史研究所院史研究室，薛攀皋文集。2008。 Xue,Pangao: Research on the history of Chinese Academy of Sciences Institute, Pangao Xue collected works.2008. Unpublished.

his power, among whom are many patriots sacrificing almost all. If I can devote my life in the reconstruction of the new country, and that is also a contribution for the victory."[251] Qian's words, to some extent, are a microcosm of the thinking of many engineers and scientists in the early PRC.[252]

The model whereby CAS became a dual organization of both science technology management and scientific research was ended in 1954. Afterwards, the new Constitution and the Organic Law of the State Council was announced, stating that the CAS was no longer a government department but "the country's highest academic institution under the leadership of the State Council". The new Constitution also defined clearly the responsibilities of CAS, that is, to promote the transformation of organization structure in order to ensure the voice of other research institutions outside the CAS system (to promote academic democracy), and to ensure that CAS would become "a center uniting national scientists, leading and advancing the national scientific course".[253] However, repeated discussions were raised on the establishment of an effective mechanism to achieve scientific leadership in CAS. Finally, the CAS Party Committee proposed the idea of setting up an Academician Division, hoping to transform the general policy directives of research objectives into specific scientific choices, through the efforts of the Division and its board members.[254]

At the first session, division members numbered 233. They were guided by three principles: academic achievement, promotion of the disciplines, and loyalty to the people's

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[251] 葛能全：钱三强年谱长编.科学出版社，2013。Ge,Quanneng: Chronicle of Sanqiang Qain, Beijing: Science Press, 2013: 149 .The slogan made by Dr. Joliot is to resisting Nazi Germany invaded France. 2013:149.

[252] 路振朝、王扬宗：20 世纪五六十年代中国科学家的科研时间问题。科学文化评论。第一卷第二期 2004.5-24 页。Lu,Zhenchao;Wang, Yangzong: Research time issues of Chinese scientists in the 1950s -1960s. Scientific and cultural comment. Volume II 2004:5-24.

[253] Shuping Yao: Chinese Intellectuals and Science A History of the Chinese Academy of Sciences (CAS). Science in Context, 3,1989 :447

[254] The division members in China are not the same as the academicians of many foreign countries. It is not an job position inside the government, The members has no right to make decision on scientific and engineering plans. However, it is not just a honorable title for science and technology elites. It is most a new attempt to gather elite scientists and engineers to participate with scientific and engineering decisions by CCP government.

cause. All division members had to go through a political investigation as required by the third criterion. The academic Divisions included almost all of China's most prestigious scientists - both inside and outside the CAS. Included were a Division of Mathematics and Physics, a Division of Biological and Earth Sciences (including medicine and agriculture), a Division of Technological Sciences (including industrial applications and engineering), and a Division of Philosophical and Social Sciences. Scientists were enthusiastic about the establishment of the Divisions and considered election as a division member to be a great honor.[255]

Besides scientists working in the CAS, division members also included university professors, engineers and researchers in production units, which were particularly prominent in the Division of Technological Sciences. The constitution of division members with non-CAS members also indicated that the Academician Division was founded as a tool to implement research plans and to make CAS "a center uniting national science and technology elites, leading and advancing the national scientific course."[256]

Seen from the Division of Technological Sciences, the 36 members in 1955 accounted for 20% of all 3 Divisions of natural sciences. Judging by educational background, 30 of them had studied abroad and obtained degrees, accounting for 83%.[257] Thus, most of the division members were engineering and technical experts with overseas experience, which also reflected the popularity of studying abroad for master and doctoral degrees in China in the 20th century. Only six members had only received domestic education, accounting for 17%. The major universities where the 36 members received their highest education were Tsinghua University, Peking University, followed by Jiaotong University, Tongji University, Northern University, and so on. These universities, to some extent, represented the highest

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255 宋振能：中国科学院建立专门委员制度回顾，中国科技史料，1991:4。 Song, Zhenneng: Review on the Establishing of Specialized Committee System in CAS. Chinese Science and Technology Historical Material , 1991 (4).

256 Science and Revolution. chapter 3,the 7th references.

257 According to China Chinese Scientific elites record (Popular Science Press, 1988) in statistics . Physics and Chemistry of the Faculty, the Faculty of Biological and technical subjects academician total of 173 people, but only 172 was on the list ,Prof. Liu, Dunzhen's record was not included.

level of academic education in China in the 1920s and 1930s.

From the academic degrees of the 36 members, 11 had Doctoral Degrees, accounting for 30% of all members; 13 had Master Degrees, accounting for 36%; 10 had Bachelor Degree, accounting for 28%; only one had no academic degree. The above explanation shows that division members were highly trained in technology and engineering. Their educational background also reflected the educational trends and main source of technological and engineering elites from the 1910s to 1940s in China.

The establishment of an Academician Division enhanced the academic status of the CAS and changed the attitude of many scientists towards the CAS to some extent.[258] In January 1956, the CCP Central Committee held a conference on intellectuals, in which Zhou Enlai gave a speech titled "Report on Issues of Intellectuals" on behalf of the CCP Central Committee.[259] The report stated the Party's political estimation of intellectuals, that the majority of intellectuals had been part of the proletariat. Thus the Party should "utilize the use and arrangements of intellectuals" and "give them the due trust and support".

Meanwhile, the specialized institues of CAS were gradually formed. The institutes can be classified into three types. The first type is made up of institues, in particular in Shanghai, Beijing and Nanjing, with histories of KMT government period. They include: institues of theoretical physics, social science and mathematics in Beijing; institues of astronomy and geology mainly in Nanjing; institutes of applied atomic energy, biochemistry as well as botany. They conduct a relatively large share of basic research. The second type of institutes is founded mainly in the second half of 1950s, as part of the 12-year plan with its emphasis on technology and military research mainly. This type of institues is mailyin northeast China which marked continuity of technology and engineering personnel is

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[258] 张稼夫：庚申忆逝。陕西人民出版社。1984：第 131-132 页。Zhang,Jiafu: Gengkun Memoirs. Shanxi People' Publishing House.1984：131-132.

[259] 中共中央文献编辑委员会:周恩来选集（下卷）。北京：人民出版社 。1981年。CCP Central Committee document ed.: Zhou Enlai anthology (2nd volume),Beijing: People's Publishing House 1981 :158-189.

found. They include institutes of semiconductor research, electronics, optics and metal research and so on. The third number of this type instiues grew fast from one in 1950 to 26 in 1984.[260] The type is to help the backward regions such as Xinjiang, Yunnan and Sichuan which are in Southwest China. In that way, the system of CAS research institutes in the whole country was founded.

Following the transformation of attitudes towards intellectuals within the Party, the academic Divisions performed several important tasks:

1. Working out the long-range (twelve-year) development plan for science and technology. More than 1,000 scientists throughout the country were involved in this, many of them academic division members, including 360 scientists from the CAS.
2. Choosing recipients of the CAS science awards. The CAS began to award prizes for natural science in 1955, and all of the meticulous work involved in selecting prize winners was carried out in the Divisions. The prizes recognized creative work and encouraged better scientific research.
3. Organizing academic conferences and academic activities. The Divisions, in conjunction with relevant departments, organized symposia on genetics, conferences on mechanics, and integrated surveys. The Divisions also were responsible for coordinating research work in metallurgy. They organized and popularized the use of isotopes and other such projects.
4. Setting the orientation and tasks for various research institutes and selecting and promoting research fellows. When the Divisions were organized, a system of academicians was also envisaged. However, it was felt that the time was not yet ripe for setting up such a system. At the Second General Assembly of Division Members, on May 1957, 21 additional division members were elected.

However, the plan to adopt a system of academicians was discarded because the Party Central Committee opposed it; in the aftermath of the Anti-rightist Struggle, Party faith in

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[260] The data is based on the book: 当代中国编辑部：中国科学院。北京：中国社会科学出版社。1994。Contemporary china Editorial, Contemporary China: Chinese Academy of Science. Beijing: China Social Sciences Press.1994:5-7.

intellectuals had been eroded. The Divisional member setup became suspect, and the General Assembly of Division Members was no longer convened.

Looking back, the Academician Division system was, after all, a historical choice of a certain social environment. First, the decision was based on the general principle of scientific development. The authoritarian structure of the scientific community, honor assignment within it as the motivation and social function of scientific elites, constituted the driving force of establishing the Division system. Meanwhile, the Party's leadership endowed the Division system with special purposes, which was to ensure the leadership of the scientific work of the Party and the implementation of its scientific principles and policies. The multiple roles of the Division attached itself multiple social significances and functions, as the manifestation of the interaction between the internal demand of the scientific community and the political goals of the Party. Therefore, the Division performed different roles according to different political objectives at different times.

5.3.2 Establishing the National Academy of Engineering

Since the founding of the PRC, Chinese engineers had been working to establish their professional organization. The forerunner of CAS, the All-China Federation of Natural Science Societies, formed a broad horizontal link across the engineering community through scientific societies of different disciplines. Within the scientific engineering community, many engineers believed that the ACFNSS was their engineering organization, and even denied the status of CAS as the highest academic community. However, with the birth of the Division system, engineers gradually found that they could seek for more resources for the research of technological sciences and implementation of engineering projects in the CAS than in the ACFNSS. Experts in technological sciences and engineers began to seek more chances to develop engineering and technical disciplines inside of CAS. However, engineering and technical experts did not receive due recognition in the CAS.

The two forerunners of the CAS, the Academia Sinica, and the Peking Academy, had been engaged mainly in basic research. When the CAS was founded, a concerted effort was made to move in the direction of applied science. In the early 1950s, the CAS worked to improve industrial and agricultural production and surveyed the country's conditions and its natural resources. However, scientists continued to carry out the basic research tasks they had been engaged in for many years. The CAS ignored the development of the technological sciences, such as metals, mechanics, and optics. It must be confessed, however, that because the CAS had traditionally been rooted in the basic sciences - such as mathematics, physics, chemistry, astronomy, earth science and biology - and had under its aegis many eminent scholars in these fields, development of the technological sciences had always been largely ignored.

The situation changed five or six years after the PRC's founding. With the shift of national science and technology tasks in 1956-1958, technological sciences began to gain more and more attention. In 1956, the State Council put forward the slogan of "March of Science"; formulated "1956-1967 Scientific Technology Development Vision" to specify the development goal of "Four Modernizations". In the most successful 12-year scientific technology plan, as recognized by all, technical science and engineering projects accounted for the majority. Especially after 1958, "Two Bombs, One Satellite" became the project strongly supported by the government in the 1960s, followed by an overall inclination of policy towards technological sciences. In order to accommodate the change, the 7th and 2nd National Machinery Industry were set up to undertake the research tasks of creating missiles and atomic bombs respectively. The technical and engineering research projects also increased steadily in CAS. In a report of 1982, the distribution of CAS in the various scientific disciplines, technical sciences was 29.1%.[261]

Different from scientist division members working in the institutions of CAS, most members of the Division of Technological Sciences were working in industrial sectors where they undertook key national projects. In the early 1980s, significant achievements

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[261] Chinese Economic Years book.1982:360.

had been made in the field of engineering science and the engineering and technical community grew stronger, asking for the establishment of a professional organization for engineers and technicians for recognition similar with CAS scientists. Materiel engineer and head of the Institute of Corrosion and Protection of Metals, Shi Changxu (师昌绪) argued, during the discussion on the Academy of Engineering in the 1980s, that: the Division system of CAS helped to promote the establishment of the Academy of Engineering: "The establishment of Academician Division of CAS defined academic status of CAS in China. Associating the corresponding status of engineering and technical experts, we proposed to establish Academy of Engineering."[262]

Seen as the catalyst for the establishment of the Academy of Engineering, the "Bohai II" Incident on November 25 1979 led to 72 deaths, arousing heated discussion on the Engineer Accountability System and engineers' due responsibilities and interests. In terms of accountability, the Minister for the Petroleum Industry department Song Zhenming (宋振明), was removed from office; Deputy Prime Minister geological engineer Kang Shien (康世恩) received a serious demerit punishment; the main responsible persons, as well as engineers and technicians, were sentenced to criminal penalties.[263] The handling of "Bohai II," Incident raised much concern from engineers and technicians. Many engineers argued that for too long engineers and technicians had undertaken great responsibilities while remaining little administrative power, causing that the administrative directives should be followed when the leaders' judgment was different from engineers'. Due to the science and technology management system of the China model, the administrative power and responsibilities of technical engineering personnel deviated from the common standards of the technology and engineering community. Engineers and technicians were

[262] 师昌绪：中国科学院技术科学部的工作报告，中国科学院院刊，1994年第三期214-216。Shi Changxu: Work report of the division of Technological Sciences, Chinese Academy of Sciences Publications, 3rd Issue,1994:214-216.

[263] 渤海二号事故专辑，国家劳动总局劳动保护局，国家劳动总局劳动保护科学研究所编。劳动出版社。内部发行。The National Labor Bureau of Labor Protection Science Research Institute compiled: Bohai accident album, the National Labor Bureau of Labor Protection Agency, Labor Press. Internal distribution.

asked to balance their position, power and responsibilities to claim their due rights and interests, which was also one factor prompting the founding of the Chinese Academy of Engineering.

Based on the appeals of engineers, the Division of Technological Sciences held the Division Assembly in Changchun in 1981. Presided over by material engineer Li Xun (李熏), Deputy President of CAS and Director of Division of Technological Sciences, the Assembly proposed establishing the Chinese Academy of Engineering, and assigned four division members of hydraulic engineer Zhang Guangdou (张光斗), mechanical engineer Wu Zhonghua (吴仲华), electronics engineer Luo Peilin (罗沛霖) and material engineer, Shi Changxu (师昌绪) to discuss its necessity and preliminary scheme. On September 17 1982, Guangming Daily published an article titled "Technological Sciences Must Be Developed to Achieve the 'Four Modernizations'" signed by the above four members. The theme was "why and how to develop Technological Sciences in China".

After a discussion and exploration of the subject, the scientific circles gradually formed a consensus that to value the technological sciences was to enhance the academic status of the technological sciences and of technical engineering experts. At the annual NPC and CPPCC meetings, representatives from technological sciences and committee members submitted proposals for establishing a National Academic Institution with engineering and technology experts as part of its main body.

Ten years after the first proposal, six division members from university science Divisions and industry sectors again put forward the proposal of establishing a Chinese Academy of Engineering in the spring of 1992, they were: Zhang Guangdou (from Tsinghua University), Wang Daheng (王大珩, optical engineer, from Chinese Academy of Space Science and Applied Research Center), Shi Changxu (Special Adviser of the National Natural Science Foundation and Director of Technological Sciences at CAS), Zhang Wei (张维, civil engineer，from Tsinghua University), Hou Xianglin (侯祥麟, chemical engineer, from Oil and Natural Gas Corporation), Luo Peilin (from Ministry of Electronics Industry). The joint proposal was drafted by Luo Peilin and printed on April 21

1992 "with about 2,000 words, briefing the development of technological sciences at home and abroad and the necessity of establishing an Academy of Engineering, along with the ideas and assumptions about the nature and main tasks of the Academy".

Through the efforts of engineers, on November 12 1993, the State Council finally approved "the proposal of establishing a Chinese Academy of Engineering", specifying the name of the institute as "Chinese Academy of Engineering" and of its members as "academician", "consistent with its nature of honor and convenient for international communications and exchange".[264] It stipulated that the CAE should be an academic community constituted of scientists and engineers with significant contributions in the fields of technology and engineering, rather than an administrative body. The discussion and proposal of the establishment plan should be completed mainly by scientists and technical experts, and should be submitted to the CCP Central Committee and State Council to after extensive canvassing of the views of interested parties. The CAE means to be a virtual body. After its establishment, the CAE would be a public institution directly under the State Council, with a working body affiliated to the State Science and Technology Commission.

The establishment of the CAE also showed the recognition of the engineering and technical cadres and their significant contribution to the Chinese scientific community. It was also a great achievement made by the Chinese engineering and technical elite in pursuit of their own rights and interests.

5.3.3 The Academies between Autonomy and Political Planning.

The mission of Academia Sinica was scientific research, while the mission of CAS was to take advantage of modern scientific achievements to serve industrial, agricultural and national defense construction. The shift of research direction from "science for science" to "science for the people" meant that its independence and autonomy were

[264] February 25 1994, the State Council approved notify the State Science and Technology Commission, the establishment of Chinese Academy of Engineering.

sacrificed significantly science became a tool to serve national construction. From the CCP's point of view, the new mission was to overcome the defects of the old research system, namely the lack of coordination, duplication of efforts, lack of funds and regarding social needs. In 1952, Chen Boda mentioned in his speech to a CAS researcher, the major work of the CAS should be complied with the urgent needs of the people, the current tasks and planned tasks of national construction,[265] which transformed the scientific research system, from independent and undisciplined research to planned and designated research closely related to actual needs.

Such a mission was not what intellectuals had envisioned. At the 204th meeting of the Government Administration Council in January 1954, Guo Moruo, then president of CAS, addressed in the CAS Working Report two basic problems of Chinese science and technology development, talent supplementation and the academic autonomy of the CAS. He said that intellectuals of the CAS were conveying the message that the more time and autonomy they received, the higher the quantity and quality of scientific and technical workers would be. However, the CCP Central Committee thought that the CAS was shortly founded with no mature condition like the Academia Sinica in the National Government period, and that scientists shouldn't have too much administrative power. Therefore, the idea of "Experts Governing CAS" failed, while under the planned scientific system, the research direction and priorities of scientific and technical workers were directed to the country, and scientific and technical experts had not much influerence in decision making within the CAS.

After the First General Assembly of division members in 1955, experts earnestly hoped to keep the initiative. Therefore, in May 1957, when the Second General Assembly of Division Members was held in Beijing, many division members presented their views vehemently. They spoke at great length about such problems as how to run the CAS. However, the day after the assembly adjourned, the People's Daily published an article

[265] 陈伯达. 论我国的科学工作。北京:人民出版社，1956。Chen,Boda: On our scientific work, Beijing: People's Publishing House, 1956: 11.

entitled “The Working Class Is Talking” - signaling a counter attack against the rightists. The experts’ criticisms and suggestions were labeled anti-Party and antisocialist. They came to be considered “competitive political opponents” and their position in China was therefore not legitimate.

During this period, many critics or views were criticized as “rightist opinions”. In the Anti-rightist Struggle, 11 division members were misjudged as “rightist”, namely, chemist Zeng Zhaolun (曾昭抡), physicist Yu Ruihuang (余瑞璜), chemist Yuan Hanqing (袁翰青), electronic engineer Meng Zhaoying (孟昭英), physicist Qian Weichang (钱伟长), biologist Liu Sichi (刘思炽), agronomist Sheng Xingsheng (盛形笙), geologist Xie Jiarong (谢家荣), mechanical engineer Lei Yaojue (雷天觉), histrorian Xiang Da (向达) and sociologist Fei Xiaotong (费孝通). On June 21, 1958, the Academy Executive Committee of CAS revoked the Division member position of the 11 “rightists”. [266]

After the Anti-rightist Struggle, the CAS redoubled Party supervision in the same way as was being done throughout the country. All research institutes were provided with deputy directors who were Party members. It was made clear that all research institutes should follow the director responsibility system, with the Division of Labor under the leadership of the Party Committee. A Soviet advisor to the CAS Chemistry Institute in Peking, noted in 1958 that “the Institute has no learned council of leading scientists, no curriculum committee, no cooperative council that could discuss the program, study reports, and evaluate the findings and opinions of the individual research workers, as was done in our Moscow Institute”[267]

The prejudice against research work did not weaken after the Great Leap Forward. The controversy over theory and practice was an ever-present millstone around the necks of engineers. In those days, when politics controlled everything, scientists had little or no input. Their freedom to do research was limited. This had its advantages when the state

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[266] 樊洪业:中国科学院编年史（1949—1999)。上海科技教育出版社，1999。 Fan,Hongye: Chinese Academy of Chronicles (1949-1999), Shanghai: Science and Technology Education Press, 1999: 40.

[267] Mikhail A. Klochko: Soviet Scientist in Red China. New York: F. Praeger, 1964:14.

wanted to centralize resources so as to carry out large-scale projects. It meant that China could develop atom and hydrogen bombs, missiles, and artificial satellites on her own, despite the fact that the overall level of science and technology was not high, and no important discoveries or inventions were being made. On the other hand, lack of freedom inhibited engineers from giving free rein to their creativity.

Although the science and technology management system in China has undergone repeated reforms and adjustments in the subsequent decades, the administrative function of key academic institutions and the research function of science and administration agencies never separated completely. Due to this remaining intersection and infiltration, engineers within the system were forced to embark on a different career path from their counterparts in Western countries. They needed not only to make innovations in the field of engineering, but also strive to prompt scientific and technological institutionalization in China based on the experience of science and technology institutionalization in the West. Outstanding engineers held different administrative positions in order to exercise some administrative functions within the system and to promote the development of science and technology institutionalization. Under the Chinese management system, this was an approach for engineers to seek autonomy. As physicists Qian Sanqiang put it, "focusing on non-research activities should be seen as an investment for future return,"[268] which may reflect the government's point of view.

[268] Qian, Sanqiang: The Development of Natural Science in New China. People's China, Sep 15 ,1953,in U.S. Consulate General, Hong Kong, Survey of the China Mainland Press:673.

Chapter 6 Conclusion: Engineers and Society

In this dissertation, the author has paid attention to the development of the engineering profession in the PRC and has discussed the status of the engineering profession from the founding of the PRC to the 1980s. The author has focused on the development and change of Chinese engineers and explored the factors affecting the development of engineers in socialist China. The concluding chapter will first summarize the findings and highlight their significance; then, it will find out the characteristics of Chinese engineers from cultural and political aspects. Finally, by taking a historical and comparative perspective, this chapter also tries to reach a better understanding of China's engineering profession.

6.1 The formation of the engineering profession: A summary

In chapter 2, this paper gave a detailed discussion of the development of Chinese engineers after the founding of the PRC in 1949. In addition, the author still wants to summarize the development process of Chinese engineering, from its start to maturity, in another way. As opposed to the historical method used before, the author wants to divide engineers into four generations according to their different social environments. The division into four generations of engineers includes the following factors: Knowledge structure, technical capacity and the educational backgrounds and career directions of the engineers, their social background and scientific and technological policies, which are all different depending on the historical stage of engineering.

1. The first generation of Chinese engineers was born after the reform and modification of laws in the late Qing Dynasty. Owing to the desire to make a prosperous country with a powerful army, young students were sent to Japan, Western Europe or America to study,

including the earliest Chinese Educational Mission,[269] the Boxer Indemnity Scholarship Program,[270] Jixun Scholarship Program,[271] cultivating many modern engineers. Most of them received primary school education and even higher education at home. After going abroad, they furthered their studies and obtained specialized knowledge and experience in the field and had good training in engineering science. These engineers included, for example, one of the founders of the Chinese Institute of Engineers railway engineer Zhan Tianyou (詹天佑), and important leader of the Chinese Institute of Engineers sanitary engineer Xu Peihuang (徐佩璜), Zhou Ren (周仁), a metallurgical engineer who was the Director of the Institute of Central Research, and Hu Boyuan (胡博渊), a mining and metallurgy engineer. All of these figures became pioneers in different engineering disciplines in modern China.

In the relationship between learning and usage, this generation focused on construction according to social ideological trends at that time, thus the importance of knowledge was highlighted, and it was easier for intellectuals to be admitted into society. Therefore, this generation of engineers was likely to have confidence in the value of academia first. From the aspect of ideological change, the abolishment of imperial examinations cut the generation of engineers off from traditional ways. On the one hand, imperial examinations lost their previous political impact and social status, and on the other hand, they still had social influence due to cultural factors. Since the engineers had a favorable traditional education in childhood alongside foreign education in their youth, which gave them a relatively complete and direct cognition of advanced western thoughts, most of them took part in big engineering projects following foreign engineers and went

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[269] Chinese Educational Mission(1872–1881) was the pioneering but frustrated attempt by reform minded officials of the Qing dynasty to educate a group of 120 Chinese teenage students in the United States.

[270] The Boxer Indemnity Scholarship Program (庚子赔款奖学金) was a scholarship program funded by Boxer Rebellion indemnity money paid to the United States that provided for Chinese students to study in the U.S. It has been called "the most important scheme for educating Chinese students in America and arguably the most consequential and successful in the entire foreign-study movement of twentieth century China."

[271] Jixun Scholarship program(1912-1913) is the first government-finazied scholarship program by Republic of China.

through the process from study to independence. Their knowledge structure comprised of foreign and national knowledge, meaning that their generation would have a broad vision and profound traditional spirit, as well as a solid academic foundation. This generation was, on the one hand, mainly driven by a socially-conservative complex (since the country was in peril when they were at the stage of learning), and, on the other, they were devoted to the course of "saving the country by science and engaging in industry" because they were affected by practical ideas.

This generation of engineers mainly majored in metallurgy, geology, railway and civil engineering, which was in line with the mainstream of world engineering development in the early 20th century. After 1949, some engineers in the mainland became the dominant force of socialist China, and they played a significant role in the 1950s when the country carried out construction in full swing. However, they were in a contradictory relationship with the CCP, and they were not fully relied upon by the CCP after the country's ideological transition. As such, they became a major object of suppression in political movements like the anti-rightists, anti-academic authority, and the Cultural Revolution. After the 1980s, they were reappraised and respected, and most of them went on to become authority figures in their field.

2. Engineers who were born after the 1920s and graduated from college before 1949 were considered the second generation of engineers. This generation grew up in the period filled with the warlord dogfights of the 1920s and experienced the second Sino-Japanese war after their graduation. Although they received a good school education and on-the-job training from the previous generation, they had no big projects to work on and thus lacked chances to practice in their youth because of turmoil and war, economic depression and reduction of investment. It was not until the 1950s to 1960s that they were active in the engineering field in a real sense. Due to all kinds of conditional limitations, few of them studied abroad, and most of them graduated from domestic universities. In this period, local universities started to set up engineering departments, and the return of overseas

students made the development of these departments possible within the country. Owing the attention the government paid to education, the number of second-generation engineers greatly exceeded that of the first generation. Most second-generation engineers experienced a society with two different ideologies (capitalism and communism), and they were quickly devoted to communist construction. In the period when China received help from the Soviet Union, they took part in the 156 Projects and other extending projects alongside first-generation engineers and Soviet experts. These projects allowed them to accumulate much practical experience. Under difficult conditions, they made historical contributions to show the superiority of socialism by advancing the path paved by the first generation. Under the guidance of policies developing higher education formulated by the Communist Party, many of them devoted themselves to engineering education and cultivated a huge number of engineers who were regarded as the third generation in schools, research institutions and enterprises.

3. Third-generation engineers graduated from university after 1949, and most of them were born in the 1930s-1940s. They spent their adolescence in a time when people had to drift from place to place and the masses had no means to live. Thus their elementary and secondary school education was far behind that of the first and second generations. Fortunately, they went to college where they received good moral and professional education after 1949, and they studied hard in a social environment that was awash with revolution. At that time, the consumption level was very low, but people's lives were greatly improved compared with the war years, and universities were open to people with no tuition fees. Generally speaking, this group of young students was happy and had a good vision of the future of socialism. They went to college with the dream of devoting themselves to the large-scale economic construction of the nation. It is worth noting that since the Chinese Communist regime aimed at the eventual full mobilization of women in production, women received unprecedented amounts of work and study experience and their participation in various fields was improved, including engineering. In this generation

of engineers, the proportion of female engineers was much higher than that of the former two generations.[272]

In terms of their educational background, this generation of engineers did not receive higher education. At the time, since the country had just begun economic construction (and the numbers of talented engineers and technicians cultivated during the period when China was under the rule of KMT government were not sufficient), the number of first- and second-generation engineers was very few and they could not handle the industrialization plan after 1949. In addition, the educational degree system had not matured; for example, undergraduates enrolled in 1949-1950 had to accept government to graduate in advance, and thus they studied for only three years. At that time, a postgraduate system was not under consideration, and the international situation and the bad relationship with the Soviet Union resulted in a lack of channels for studying abroad, through which engineers of this generation could obtain a higher academic degree. Although many of them were "professor-level" engineers, they did not have a higher academic degree. Only a few of them were lucky to be chosen as overseas students at state expense by the government to further their study in the Soviet Union and Eastern Europe and gained the candidate doctorate degrees (Russian: кандидат наук, Kandidat Nauk) or doctorate degrees due to their family background and their excellence in character and learning. However, since their knowledge composition was simple and superficial and lacked a systematic traditional cultural background, they were inclined to the left-leaning values and cultures of the Soviet Union. Therefore, engineers of this generation were inevitably different to the first two generations in terms of values. The most obvious difference was that the first two generations pursued independence of character, had interest in "differences"; while the third generation of engineers lacked a western democratic spirit for reference and had unified pursuits which were demonstrated by their

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[272] Gui, Zhizhen (1996) "Science and technology in China: successes and challenges for women's participation," in Mary-Louise Kearney and Anne Holden Ronning (eds) :Women and the University Curriculum towards Equality, Democracy and Peace, London: Jessica Kingsley Publishers, 169–76.

strong desire for "common" values and suppression of individuality. The result was that the third-generation engineers had a weak sense of innovation.

In terms of knowledge, they seldom had professional books to read. Since engineering education was partial to specialized education, their knowledge was too narrow, and they were often only qualified for a few occupations. After they entered the service, due to the international blockade, they could hardly read publications of other countries except the Soviet Union, and thus their speed of knowledge update was very slow and, more often, they accumulated experience. As for investigative trips abroad, their chances were even less. Although chances to attend meetings abroad or investigate were given, all of these opportunities were taken by famous engineers of the first or second generations. Conditions did not provide them with a good environment to read in their secondary school time, their English was not as good as that of the first two generations. After the educational reform in the 1950s, their foreign language was changed to Russian and foreign language teaching did not receive enough attention, which meant that the English ability of this generation was inferior to that of the first two generations; this had an influence on their ability to communicate with other countries as well as their direct absorption of foreign theories and experience.

Engineers of this generation were restricted by various political and economic factors. For engineers who were relatively older, they were caught up in the Great Leap Forward and the three-years of economic difficulties when they just started to work. Later on, because of the call which encouraged educated youths to go and work in mountainous and rural areas, most postgraduates took part in work in the countryside, thus very few engineers participated in engineering projects and lacked practical ability in the field. As for the group, it was not until 1980s-1990s, after the economic reform, that they made achievements. The sense of historical responsibility of these engineers came from pushing the fourth generation to the cutting-edge of engineering and making up the gap between the third and fourth generation, caused by the Cultural Revolution, as soon as possible.

4. The fourth generation was born after the founding of the PRC in 1949 and graduated from higher engineering schools that had rebounded after the Cultural Revolution. Certainly, the number of the fourth-generation engineers surpassed the total number of the first three generations. From the aspect of educational background, the number of the fourth generation of engineers who got master or doctorate degrees was much higher than that of the first three generations.

Engineers of the fourth generation were of different ages, because some elder ones were caught up in the Cultural Revolution and the time when educated students were encouraged to go to mountainous and rural areas, meaning they missed their studies. However, since they had considerable work experience and had studied hard. In addition, others of them started their middle school and college education after the Cultural Revolution. Thus they had a favorable study environment but lacked practical work experience. Furthermore, they were impacted by market economy and fickle social conditions, with their psychology and professional ethics negatively affected as a result. The spirit of engaging in scholarship and good design for them was not as strong as in former generations. However, they had a relatively higher level of foreign language ability, they knew international conditions, had a stronger ability to accept new things, and had a broader scope of knowledge. New careers came into being, such as electronic engineering, information engineering, network engineering, and bioengineering. In some emerging scientific and technological fields, the knowledge of some engineers was even stronger in terms of comprehensiveness and complexity. In emerging areas such as computing, the ability and advantage of Chinese engineers made an impact across the globe. However, the effect of traditional Chinese culture on this generation was much weaker than in the first and second generations and little weaker than that in the third generation. Since they received their college education in the open socialist China of the 1980s, their thinking was diversified.

To sum up, engineers of these four generations were considerably different in terms of their ability and knowledge structure, a fact related to the social aspect of engineering and engineers. It also proved that engineers of various social backgrounds were different in the engineering projects they undertook, and in their capacities and professional standards. Due to these differences, there were special relationships between engineers of the four generations. The relationship between generations was reflected, firstly, in differences between groups of the same age, which resulted from the different leading roles of engineers in different generations; for example, the western educated tradition in the first and second generation of engineers was different to the Soviet technological tradition and CCP tradition of the third and fourth generation. Secondly, it was reflected in the relationship between the higher and lower levels in "units" based on status due to differences in age and the Confucian tradition of respecting elder and obeying superiors; the situation of assessing qualifications according to age was especially prevalent in China.

These two differences were of great importance in China. Moreover, in the radical period when China went through several political movements, the two differences resulted in scientific and technological policies tending to accelerate conflicts between generations, named the "turning over the doctrines of Confucius and Mencius and Stopping Fawning on Foreign Powers" (反孔孟之道、反从洋媚外). The conflicts resulted in discontinuities between generations, and thus gave rise to obstacles in the continuing advance of technical knowledge and the scientific spirit of engineers. However, despite being criticized by radicals, the effect of cultures and politics behind the two differences was rooted, and caused some of the other professional characteristics of Chinese engineers.

6.2 Engineers and culture

Chinese engineers in real sense did not come into being until the early 20th century, before then, the term "engineer" was just a loan word and there was no occupation in China called engineering. However, technical experts who specialized in solving practical engineering problems did exist a long time ago in ancient China; master builders, for example, who managed the construction style of national buildings, supervisors who were in control of river and water engineering, and craftsman who managed iron-making and weapons manufacturing in iron bases. After the engineering occupation had come into being, these old occupations were gradually transformed into the engineering occupation. In the process of modern career transitions, although they accepted complete education of western scientific system, Chinese engineers were greatly affected by Chinese traditional cultures, which mainly included: 1. characteristics of craftsmanship; 2. a scientific spirit; and 3. a sense of social responsibility.

Since there were no scientific theories in ancient times, engineering technology was improved through experience and summarization of experience, which matched the practical reason of ancient China. Craftsmen with creativity undertook some famous ancient engineering projects, and people like Mozi (墨子) and Shen Kuo (沈括), who had an interest in engineering technological innovation, were very few. The Mohist school, which combined cultural knowledge with craftsmanship was defeated and annihilated in competition with Confucianism, Taoism, and Legalism, which marked the division of Chinese traditional cultures and high-level intellectuals and craftsmen. As for Confucianism, which supported the whole of Chinese thought, its historical status in the scientific and technological development of ancient China had been an issue concerned with the academic circles.[273] However, one thing for certain was that it insisted in putting agriculture in a higher position than industry. For example, Confucius pointed out that Shu and Ji could rule the world because of their outstanding contributions to agriculture.[274] Compared with the great task of managing the country, what craftsmen needed to know were skills.[275] Skills did have some merits, but they would possibly obstruct management

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[273] In the 1950s, the British scholar Joseph Needham believes that the Confucian contribution to science is almost entirely negative (mentioned in its Science and Civilization in China Volume II) However, from the beginning of the 1980s, Needham, whose view has been questioned by many Chinese scholars and opposition put forward the Confucian influence on the development of Chinese science and technology is very large, and a positive impact on the majority.

[274] 躬稼而有天下的(论语·宪问)

[275] 君子谋道不谋食，君子忧道不忧贫 (论语·卫灵公)。儒家以兴灭国，继绝世，举逸民 (论语·尧曰)为己任，致力于探求治国大道。

of state affairs. Thus gentlemen should not concern themselves with that.[276] It was said that a mechanist must have something to do related to machinery and people who worked on machinery must have an interest in machines. If an interest in machinery wasn't at heart, they would be unprepared; if a person was unprepared, their mind would not be peaceful, and if their mind was not peaceful, the road is not set. This idea was widespread at the time.[277] Based on the ethical norms, ancient people even put forward "mort cheats make it honest".[278] Mainstream ideology believed that others only respected people in official positions, and only reading could make goals come true. Therefore, under the influence of the thought that "to be a scholar is to be at the top of society", engineers who grasped technological skills were excluded from intellectuals and were treated as disdainful manual workers. Moreover, their operational abilities were regarded as trickery.

This culture has been passed on still to modern times, meaning that the most excellent scholars of China (including students of engineering) were able to use pen and paper but lacked operational skills. Although Qian Xuesen was among the best students in primary school to college, he felt frustrated in MIT, where he was widely divergent. What Qian wanted was a theoretical education, but the aeronautical engineering department of MIT was proud of cultivating engineers who had practical operational abilities and could take part in production after graduation. Qian had spent most of his time in the libraries of China; while most of his American schoolmates grew up in family labs and played with car parts, bicycles, wireless operators and airplane models in barns, in basements or garages. Therefore, to finish his doctoral education Qian had to find another graduate school in America that would accept him.[279] The characteristic of modern engineers was the integrated science-technology-engineering system, that is to say, theory and practical ability were both required. However, the ancient cultural tradition of division between scholars

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276 子夏指出: 虽小道，必有可观者焉；致远恐泥，是以君子不为也。

277 庄子．天地

278 韩非子．说林

279 张纯如：钱学森传。北京: 中信出版社，2011。Chunru Zhang：Qian Biography。Beijing：Zhongxin Publishing House。2011:47-48.

and craftsmen observed by geologist Zhu Kezhen (竺可桢) in the 20th century, had not changed. Although the nation had big cities as well as wireless operators and airplanes, and we could say that we benefited a lot from modern culture, people still disdained handiwork. Students in schools still disdained manual labor, just like former scholars and officials did. To catch up with the material civilization of European and American countries, China had to develop experimental science and people had to be willing to work with their hands.[280] The education of engineers was partial to theoretical study, thus practical ability was weak. Engineers who had both engineering theory and practice could be seldom seen in China, and craftsmen with theoretical knowledge were hard to find, which inevitably resulted in falling behind contemporary scientific theories and the innovation of technical principles.

Another characteristics came from ancient craftsmen because their social status was restricted. For example, it was stipulated that craftsmen were not allowed to study with the purpose of being an official in the Northern Wei Dynasty and their children could not study in private schools, while the government of the Tang Dynasty rejected craftsmen for official positions. Therefore, ancient craftsmanship was developed at a time when it was isolated from current science. The separation of science and technology meant that most techniques of craftsmen came from imitation and transformation rather than innovation. Moreover, the ability of craftsmen was assessed according to the crafts they made. We can see the overall situation of craftsmen in China from an anecdote. In October 1864, Zuo Zongtang asked a 60-year-old Chinese artisan in a shipwright to make him a steamboat. Prosper Giquel (1835–1886) a French naval officer recorded in his diary: "Made according to the Ningbo Boat, the steamboat can accommodate two persons, front and back. The machine was completed in general with all its fittings in, which can only indicate the working principle of a steamboat, nothing else. When Zuo decided to make a trial sail on West Lake, he showed me two tools the old worker used to make the steamboat and said 'Such a simple tool indicates the wits of Chinese craftsmen, but also the backward manual

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280 竺可桢：竺可桢全集。 第2卷。上海: 上海科技出版社, 2004。Kezhen Zhu:Kezhen Zhu Collection. Volume 2, Shanghai：Shanghai Technology Press. 2004：262.

production.""[281] The differences between Chinese and foreign engineering technologies in modern times contributed to engineers having the characteristics of craftsmen, and the spirit and ability of imitation were highly developed. However, if countries, organizations and individuals, could not keep a proper balance between imitation and originality but only relied on others blindly, they will be forgotten with time.

The characteristics of imitation rather than originality seemed to have another problem, which was the shortage of scientific spirit. In the "seven liberal arts" which represented the western liberal education tradition, natural scientific factors like geometry and astronomy could be found. However, the Chinese imperial competitive examination was purely cultural, and excluded mathematics from the six arts. However, the humanism of China was utilitarian in its spiritual temperament. Confucianism advocated "humanistic pragmatism" and regarded "family harmony, country management and world peace" as its ultimate goal. The imperial examination system linked study and officialdom together. Thus the traditional Chinese education was a vocational education for the only occupation of "being officials". In Confucian cultures, Aristotle's concept of "study for knowledge" could never be found. The Confucianism philosophy was centered on the human and had no interest in logic and metaphysics. Therefore, it did not have the concept of "pure science", as western cultures had. The spiritual temperament of the Confucian cultures manifested in a facet which was similar to that of the "wise man school" in ancient Greek culture and later Roman culture, which became the pragmatism of American in the 20th century. At the end of the 19th century, the attitude of the Chinese feudal landlord class to science had some common points with that of the English gentry, being the arrogance wraught by its former independence from science. As opposed to the English aristocracy, the arrogance of scholars and officials of the Qing Dynasty had a strong nationalist sentiment - they firmly believed that the "materials" of the great China were superior to that of any other country, let alone sprits. Debates within the ruling class were not about

[281] David Pong：Shen Pao-chen and China's Modernization in the Nineteenth Century, (Cambridge Studies in Chinese History, Literature and Institutions), Cambridge University Press ,2003:110.

whether they agreed with "pragmatism" but which one was the more pragmatic. A "westernized Chinese style" and "beating someone by playing his games better" were just typical reflections of the pragmatism of Confucian cultures. However, this pragmatic spirit hindered the antagonism between occupation and Academy in thoughts of the Chinese. The humanism in Chinese traditional education was more serious than that of the west. Under the original impetus of passive learning and technical implantation, the degree of social recognition for engineering as an occupation was very low; engineers' awareness of their own role was not clear; and they conducted scientific and research activities mainly for pragmatism and survival.

Another effect of traditional culture was a strong sense of social responsibility. Chinese mainstream culture regarded neglecting personal interests and making contributions to people and the nation as a benchmarking of personal morality, and it was also true for technicians. It was said Yu The Great diverted floods to the sea through the method of dredging so as to bring people a stable living environment. In the legend, Yu spent 13 years preventing floods and did not go back home although he passed by three times, which reflects the moral standards of Chinese heroes. The old maxim "every man alive has a duty to his country" has been reflected in Chinese engineering since ancient times. The modern engineering occupation was born because of the historic mission to "save the nation by engaging in industry". The scholars who were determined to become engineers did not do so for science or their desire for the occupation but for the nation. Moreover, the Chinese Institute of Engineers obeyed national defense and economic construction policies and national industrial plans, regarding national interest as superior to everything and sacrificing one's freedom to contribute to the nation willingly as its creed.[282] After the founding of the PRC, under the influence of Socialist ideology, the sense of responsibility was even more intense in Chinese engineers, which could explain why overseas scientific and technological talents returned home to throw themselves into

[282] "Ethic Code of China Institute of Engineer" 1941 Chinese Institute of Engineers 10th Annual Meeting adopted

construction in the early days of the new China and why the engineering group still expanded regardless of the unreasonable distribution of brainpower and physical labor.

6.3 Policy and technocracy

After the Cultural Revolution, the CCP gradually turned from revolution to economic construction, and revolutionaries quit their administrative positions to be replaced by a technical elite which scholars called the 'technocracy'. The term technocracy was introduced to China as early as the beginning of the 1930s. In the article titled "Scott and Technocracy", which was published in New China Magazine in 1933,[283] the author translated it as technocratism.[284] In the first three decades of the PRC's history, the term technocracy was translated as the "dictatorship of engineers".[285] However, the "Redness" versus "Expertise" debate is more mentioned often than the "dictatorship of engineers" .

Starting in 1957, the CCP rejected the technocratic aspects of the Soviet education model and implemented much more radical policies. Mao repeatedly mobilized party members and broader sectors of the population to resist technocratic tendencies, and did so in a particularly determined fashion during the decade-long Cultural Revolution. In most instances, engineers were not confident enough to become important players on societal and political issues, until 1980, when Hu Yaobang (胡耀邦) made an important speech in commemoration of the centenary of Karl Marx's death. Hu, the Party general secretary, stated forcefully that the Party should oppose the tendency of divorcing its leadership from expertise or setting itself against experts. Instead, he said, the party should establish the concept that all leaders must be trained specialists.[286] Since then, technicians

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283 Xinzhonghua Zazhi新中华杂志

284 Zhang, Sumin, Makesidier sigaode yu Tuikenuokelaxi "Scott and technocracy. Xinzhonghua Zazhi.Shanghai.1(4)Feb.1933:28. The article focused on the ways American engineers try to solve social problems by applying the methods of the physical sciences, but it did not discuss the depth any political implication of technocracy.

285 Jiang Yiwei:Technology and politics,Study,No.16,1957:12.

286 胡耀邦：马克思主义伟大真理的光辉照耀我们前进，红旗，1983年3月第六期。Hu Yaobang: Great truth of Marxism guides us to move forward,。No.6 March.1983:2-13.

and specialists have become increasingly prominent in the circle of power.

Whether the CCP intended the emergence of technocrats after the 1980s or not, it was a chance for Chinese engineers of the third generation. Graduating from college after the liberation, they were affected by socialist culture and had a good vision of the future of socialism. Cultivated after the founding of the PRC, they belonged to a generation who had witnessed socialism and dictatorship. They were reliable in politics and had worked for several years at a grassroots level. Besides, their technical working experience became an advantage in their work as government officials.

Technocrats in China have two kinds of career path. Firstly, the people who joined the underground Communist movement during the revolutionary period, but also received training as engineers. It would be improper to say that all of these technocrats have earned their career promotions due to their technical expertise. Some of them only worked as engineers for a few years but spent several decades working as Party officials or administrators. For example, Jiang Zemin, who served as the party's general secretary, and Li Peng, who served as premier and head of China's National People's Congress, were both assigned to the party to study engineering and after finishing their training in the Soviet Union in the early 1950s, they embarked on careers that started in factories and led to important positions in the machine-building and electric power ministries.

However, it would be mistaken to believe that no one among these leaders could actually be considered a technical expert. For example, Song Jian (宋健), minister of the State Science and Technology Commission, is a cyberneticist and an expert in astronautics. He received a doctoral degree in automation at Bauman Moscow State Technical University in the 1950s and studied at Harvard and M.I.T. as a visiting scholar in 1980. He is a lifetime guest professor at Washington University in St. Louis and a part-time professor at both Tsinghua and Fudan universities. Unlike many ministers who have advanced in their careers through bureaucratic hierarchies, Song had long worked as a director and a president in several research institutions before becoming a vice minister in China's Ministry of Space Industry. In the state Council, several ministers have a career pattern similar to that of Song, such as metallurgical engineer Qi Yuanjing (戚元靖), minister of metallurgical industry, hydropower engineer Lin Hanxiong (林汉雄), minister of construction, and mechanical engineer Zou Jiahua (邹家华), vice premier.

The proportion of the party's ruling Political Bureau that was made up of individuals with science and engineering degrees had grown dramatically, increasing from none in 1982, to 50 % in 1987, 75% in 1998.[287]

However, the selection of technocrats is not based on criteria which are universalistic, scientific-technical, achievement oriented, or impersonal, as some technocratic theorists have claimed, but is based largely on the political and institutional network through which they have been promoted.[288]

In addition, the author also thinks some problems related to the technocratic leadership should receive further research, such as: Has technocratic leadership been good for China? Scientific and technical decisions made by the technocratic leadership were different to those made by revolutionaries. What manifested the technocratic characteristics? What is the effect of engineers as political leaders?

6.4 Towards a better understanding of China's engineering profession

So far, in this concluding chapter, the author has analyzed the characteristics of Chinese engineers of four generations. Furthermore, the author has discussed the cultural and political fields separately. Finally, the author intends to return to the questions posed at the beginning of the paper: What were the characteristics of Chinese engineers? What factors could affect them? How did Chinese engineers play a part in the development and growth of the PRC?

In the past four decades, the development of Chinese engineers was complex and contradictory, but it was a course that developed continuously. In expanding its

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287 Joel Andreas: Rise of the Red Engineers: the Cultural Revolution and the origins of China's new class. Stanford California: Stanford University Press.2009:246.

288 Li,Cheng: The rise of technocracy: Elite transformation and ideological change in post-Mao China. Ph.D dissertation .Princeton University,1992:300.

technological knowledge and cultivating scientific and technical talents, China had made significant achievements. After the founding of the PRC, an engineering discipline system and an engineering education system were constructed. After the educational reform of the 1950s, most integrated engineering colleges became national key engineering colleges. They trained a large number of engineering and technical personnel for national industrialization. By the end of 1989, the number of graduates who majored in engineering disciplines was 39 times that of 1949.

However, in the process of technical knowledge transformation, Chinese engineers were faced with various difficulties, including factors within the system that hindered innovation, alongside political factors. Influenced by the Soviet Union in the 1950s, Soviet technology constituted the foundation for China to develop technology and industry. In the 1960s, when China closed its national door under the slogan of independence, Chinese engineers started to explore their way out of the predicament on the construction of the Third Line; in the meantime, the Chinese government began to import new technology and equipments from Western Europe and Japan in the late 1960s, however, the scale was not broad. In the early 1970s, the direct eruption of ideological conflict put engineers and engineering education into hard times; and in the 1970s, when China opened its door to introduce technology and projects from entire western countries, engineers had to relocate and adjust themselves in terms of engineering knowledge and practice again.

We can see China gave priority to national goals instead of passing on existing technologies and adapting to national production factors. This unstable government planning and engineering training created incoherence in the knowledge of engineers. In addition, the difference between generations of engineers in China mentioned earlier also meant that engineers got lost in a circle of 'imitation- reproduction' and never got the new process of innovation.

Although to find a path appropriate for Chinese engineers, government and technological development is not easy, Chinese engineers are still working on it with passion and faith in serving the country. They live not a wealthy life but work hard; they don't have many ideological pursuits but professional goals; they do not receive great respect from society, and were even hurt by the CCP government and the masses in Cultural Revolution. However, the Chinese engineers always hold faith in making the country better. They don't like scientists who receive more attention than them, and they don't like social intelligence with a rebel spirit, they always choose to put their heart into working in silence. Moreover, the Chinese engineering group was expanding, and, meanwhile, they had accumulated a large amount of technical knowledge and capabilities in the process of learning and developing.

Fortunately, systematic reform and scientific and technological policies were inclined to provide engineers with a more loose and free environment, and Chinese engineers sought a pattern that could conform to the needs of national economic development and of technological development. In the process of probing developmental approaches, the general professional quality of Chinese engineers was improving. It is noteworthy that the capacity problem in engineering was a worldwide phenomenon, but issues such as the shortage of quality regulation, lack of experiential training opportunities, shortage of scientific spirit, the inability to intervene in political decisions, and neglect of engineering organizations.

From the aspect of technological history, although Chinese engineers had made remarkable achievements in some scientific and technological fields, their contributions to world science and technological development were not obvious, in general. After the beginning of the new technological revolution, Chinese engineers on the one hand continued to make up lessons in mechanization and electrification, and, on the other, did all they could to catch up in information. In this process, Chinese engineers may have a chance to take a lead in world science and technology history. As for the PRC, engineering professions were the key to its development and growth. It seems that the development of Chinese engineers will continue its zigzagging but progressive journey.

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People's Daily, 人民日报。

Red Flag, 红旗。

Appendix

Mechanical engineering curriculum schedule at the Tsinghua University in 20th century

The first academic year:

Before 1949	1953	1965	1993
Chinese 3*	History of Chinese Revolution 6	Basic theory of Marxism-Leninism 3.5	History of Chinese Revolution 4
English 3	Russian 12	Ideological and Political Education 2	English 8
General Physics 5	Advanced Mathematics 14	Foreign 8	Legal Basis 2
Calculus 4	General Chemistry 6	Sports 3	Military Theory 2
Descriptive Geometry	Physics 6	Advanced Mathematics 13	Sports 4
Molding Practice	Descriptive geometry and engineering drawing 8	General Physics 3.5	General Chemistry 3.5
Engineering drawing 2	Theoretical Mechanics 7	General Chemistry 3	General Physics 5
Malleable Practice	Metal Engineering 3	Descriptive geometry and engineering drawing 8	Calculus 12
Economic Introduction 3	Sports 4		Engineering Drawing and mechanical foundation 8
			Elective 2 1,4

The second academic year:

Before 1949	1953	1965	1993
Electrical theory 1,2 10	Basis of Marxism-Leninism 6	Ideological and Political Education 2	Humanities and Social Sciences 4
Static and dynamic 4	Russian 4	Foreign 8	English 8
School 3 parts	Advanced Mathematics 10	Sports 2	Sports 4
Economic Plan 2	Physics 9	Higher Mathematics 7	Physical 4
Metalworking initial 1	Descriptive geometry and engineering drawing 4	Physics 11.5	Physical Experiment 5
Differential Equations 3	Theoretical Mechanics 3	Metal Engineering 1	Linear Algebra 3.5
Chemistry 4	Mechanics of Materials 9	5.5 Theoretical Mechanics	Field theory of complex function 3
Electromagnetic Quiz 1	Mechanical principle and mechanical parts 3	6.5 electrician basis	
Mechanics of Materials 4	Metal Engineering 7		
3 Heat Machine Learning	Electrician base 8		
Metalworking Practice 1	Sports 4		
Hydraulics 3			

The third academic year:

Before 1949	1953	1965	1993
Electrical Principles 3410	Mechanical principle and mechanical parts 11	Marxism-Leninism 4	Contemporary Capitalism 2
Electrical Experiment 2	Metal Engineering 2	Ideological and Political Education 2	Chinese socialist construction 2
Chiu school 2	Electrician base 10	Sports 2	Sports 4
Thermal Engineering 3	Electric meter 5	Mechanics of Materials 5	Probability and Mathematical Statistics 3
Measuring 2	Electrical materials 3		Engineering Mechanics 4
Hydraulic experiments 1.5	Electrical machinery 13	6.5 electrician basis	Limited electives a 4
Engineering Materials 3	5 Heat Machine Learning		Elective
Thermal Engineering Experiment 2	Hydraulics and Hydraulic Machinery 3		
Electrician mathematics 3			
Experimental 1.5 Materials			
Motor Design			

The fourth academic year:

Before 1949	1953	1965	1993
Power Transmission 4	Electrical machinery 4	Marxism-4	4 Principles of Marxist Philosophy
Electrical Experiment 2	4 Heat Machine Learning	Ideological and Political Education 2	3.5 Calculation Method
3 power plant	Hydraulics and Hydraulic Machinery 3	Sports 2	Limited elective D 3-4
Paper 2	High Voltage Engineering 2	Mechanics of Materials 5	A direction electives
Thermal Engineering Experiment 2	Electric power plant substation 4	Mechanical principles and mechanical parts 4.5	Elective B direction
Motor Design	Power grid and power system 2	Electrician base 5.5	Limited elective B 3
Elective or 3 case studies	Short-circuit current 5	12.5 motor learning	
Normal radio	Power system automation and relay protection 6	Industrial electronics 6	
Motive power plant 3	Industrial electronics 6	Relay Automation 1.5	
Electrical experiments 1.5	Power Economics 3		
Distribution Project 4			
Radio Experiment 1.5			
Motor Manufacturing 2			
Motive power plant Experiment 3			
Motive power plant design 2			
2 hydropower project			
Power Plant Design			

The fifth academic year：

Before 1949	1953	1965	1993
	Power system stability 5	Marxism-5	Elective
	Power system automation and relay protection 3	Ideological and Political Education 2	Thesis
	Driving force of economic organization and planning 6	Sports 2	
	Security Fire Protection Technology 3	The high number of 3.5	
	Thesis 16	Mechanical principles and mechanical parts 2	
		Electric meter 4	
		5.5 Industrial Electronics	
		5 power grid and power systems	
		High Voltage Engineering 5	
		System power transition process 4	
		Ideological and political one	
		Sports 1	
		High Voltage Engineering 3.5	
		2.5 Power System Transients	
		Protection automation 12.5	

1953：the total academic hours are 4462

1956：the total academic hours are 2959

1993: the total academic credits are 3096

*Credit hours or Credits

Based on 方惠坚，张思敬主编：清华大学志，北京：清华大学出版社，2001。上册71-75、下册56-67页Fang, Huijian & Zhang，Sijing eds. Tsinghua University. Beijing: Tsinghua University Press, 2001.Vol.1, 71-75, Vol.2,56-57.