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Soviet Aid and the Construction of the Lanzhou Cyclotron

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Abstract: The transmission of science and technology from the Soviet Union to People's Republic of China in the mid-twentieth century is an important research area of contemporary history of science and technology. This paper takes the construction of the cyclotron in Lanzhou, China as the case to discuss the characteristics of technology transfer from the Soviet Union to China. The review of extensive archives reveals that the construction of cyclotron took place in the framework of China's nuclear weapons development. Although the transmission of science and technology from the Soviet Union to China fit into the one-way transmission-reception model in general, both the Chinese demand and the Soviet response had key influences on the transmission. In the early cyclotron construction, the Chinese side relied on the Soviets, and the mode of the cooperation between Soviet and Chinese engineers can be described as one of expert-student. In the early 1960s, the relationship between China and the Soviet Union broke down. The Soviet engineers were required to withdraw with the technical data, which created conflicts in the roles played by the Soviet engineers, most of whom chose to set the sense of professional responsibility as their highest priority. After the departure of the Soviet experts, Chinese physicists played the leading role in the project, using scientific knowledge they had, relying on the technical materials left by Soviet experts, and cooperating fully with local engineers, thus completing the cyclotron. This case can provide us with valuable clues for the understanding of transnational history of science and technology. The seemingly one-way transmission-reception model is actually influenced by the needs of both sides. While the transnational flow of knowledge is

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inevitably affected by political factors from both sides, the process is far more complex than it appears.
Keywords: cyclotron, Sino-Soviet relationship, conflict of roles, Soviet engineers, Chinese scientists

摘　要：20 世纪中叶苏联向中国的科学、技术传播是当代科技史研究的重要领域。本文以中国兰州回旋加速器的建造为案例，探讨苏联技术向中国转移的特点。通过对大量档案的梳理可见，加速器的建设是在中国核武器研发框架内进行的，虽然苏联向中国的科技传播在整体上表现为单向的传播-接受模式，但中方的需求与苏方的回应对此传播有关键影响。早期加速器建造中，中方全面依赖苏方，中苏工程师间的合作可被描述为专家-学徒模式。60 年代初，中苏关系破裂，苏联工程师被要求携技术资料撤离，这使他们陷入角色冲突，他们中的大多数选择将职业责任作为最优先的角色责任。苏联专家撤离后，中国物理学家发挥了主导作用。他们利用自己掌握的科学知识，依托苏联专家留下的技术资料，与工程人员通力合作完成了加速器建造。本案例为我们理解跨国科技史提供了宝贵线索。双方需求实际上对看似单向的传播-接受模式具有决定性影响，虽然知识的跨国流动不可避免地受双方政治因素影响，然而其具体过程远比表面上的更为复杂。
关键词：回旋加速器，中苏关系，角色冲突，苏联工程师，中国科学家

1 Introduction

From 1949 to 1966, the People's Republic of China (PRC) implemented the policy of establishing its educational and scientific research system following the Soviet model, and the Soviet Union provided aid to China to this end. The construction of the Lanzhou 兰州 cyclotron is a representative case. Li Xiubo 李秀波 and Wang Dazhou 王大洲 (2019) have provided an outline of the construction and modification of this cyclotron, and Wu Enjiu 邬恩九 (2016) briefly mentioned it in his memoirs.[1] Based on archival materials, this paper will answer the following questions: Until the end of the 1970s, the Lanzhou cyclotron remained one of the most expensive and advanced physics instruments in China. In what context, then, was such an instrument constructed? During construction, what kinds of roles did the Soviet and Chinese engineers play? Did the Soviet engineers change their attitude towards their cooperation following the deterioration of Sino-Soviet relations? And why and how was the construction carried out? In answering these questions, we not only provide a more detailed analysis of the construction of the Lanzhou cyclotron, but also clues to more general problems in the history of knowledge transmission and interaction

1 Other monographs and papers have examined Soviet assistance to Chinese nuclear physics, particularly in the manufacture of nuclear weapons (Liu, Liu, and Xie 2004, 187–195; Ichikawa 2019, 1–12; Shen 2015, 272–334; Zhang et al. 2004), but they have rarely touched on the Lanzhou cyclotron.

between the Soviet Union and China in the 1950s and 1960s, such as what was the mode of cooperation between the Soviet and Chinese professionals? What factors were more decisive in the selection of the knowledge that was transmitted? And how did scientists and engineers react to the dramatic changes in the Sino-Soviet relationship?

2 The context of the construction of the Lanzhou cyclotron

The construction of the Lanzhou cyclotron took place in the framework of the development of nuclear technology in China. In the 1950s, the PRC prioritized research on nuclear energy and the development of nuclear weapons in its national defense building and plans for the development of science and technology.[2] In order to do so, Chinese leaders turned to the Soviet Union for technical assistance. In 1950, Mao Zedong 毛泽东 (1893–1976) had already determined that China should have the atomic bomb, and began to negotiate with the Soviet Union for assistance. After a long and difficult process, Nikita Khrushchev (1894–1971) finally agreed to help China with the civil use of nuclear energy in 1955, and military use in 1957 (Shen 2015, 272–289).

In April 1955, China and the Soviet Union signed the Agreement on the Assistance of the Soviet Union to the People's Republic of China in Developing Nuclear Energy and the Use of Nuclear Energy for National Economic Needs (关于苏维埃社会主义共和国联盟援助中华人民共和国发展原子能事业以及为国民经济需要利用原子能的协定). Under this agreement, the Soviet Union would assist China in the construction of a heavy water experimental reactor and a 1.2-meter cyclotron. This cyclotron was completed in 1958 in Beijing and played an important role in the development of the atomic bomb. China thus began the construction of its first nuclear energy scientific research center (Editorial Board of *Contemporary China* 1987, 20; Ge 2013, 256; Ichikawa 2019).

In August 1956, China and the Soviet Union signed another agreement on the assistance of the Soviet Union to China in developing a nuclear energy industry and laboratories. According to this agreement, the Soviet Union would assist China in building a 1.5-meter cyclotron. In the same year, Premier Zhou Enlai 周恩来 (1898–1976) directed that a nuclear scientific research institute should be established in Lanzhou (Qian and Zhu 1987, 182). In September 1956, more than twenty members (including fifteen physicists) of the Institute of Physics, Chinese Academy of Sciences (CAS), in Beijing moved to Lanzhou, and began the establishment of the CAS Physics Laboratory (hereafter "Laboratory of Physics in Lanzhou"). This laboratory was founded in 1957, and would receive the 1.5-meter cyclotron.

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2 In October 1957, the Chinese and Soviet governments signed the Agreement on New Technologies for National Defense (Guofang xinjishu xieding 国防新技术协定) in Moscow, marking the moment when the Soviet Union began to assist China in developing nuclear weapons (Editorial Board of *Contemporary China* 1987, 21).

The Lanzhou cyclotron was capable of accelerating deuterons to 24 million electron volts, alpha particles to 48 million electron volts, and protons to 20 million electron volts.[3] It was completed in 1963, and was soon put into use in research on the hydrogen bomb, and later, with modifications, used as the main instrument for conducting research on heavy ion physics in China.

Figure 1: Stamps issued on December 30, 1958, featuring the first Chinese nuclear reactor and a 1.2-meter cyclotron.[4]

We can clearly see that the construction of the cyclotron was entirely for military purposes. Thus, in the transmission of knowledge from the Soviet Union to China, both sides played an important role in the selection of content, and sometimes, with regard to the cyclotron for example, China's demands were the more decisive. Izabella Goikhman (2010) has studied Soviet-Chinese academic interactions in the 1950s, questioning the "Impact-Response" approach from a historiographical perspective. Besides the arguments she has presented, the shaping of the content of the knowledge in transmission should also be analyzed, and the case of Lanzhou cyclotron provides us with a practical example for further research.

3 Soviet aid in the construction of the Lanzhou cyclotron

The 1.5-meter cyclotron project, code-named "613," was carried out by the Third Ministry of Machine Building of China.[5] The Soviet Union would provide China with the apparatus, materials, and design plans for the cyclotron, and dispatch experts to

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3 "1959 nian zhongda yanjiu xiangmu biao: Jiasuqi" 1959 年重大研究项目表：加速器 [List of Major Research Projects in 1959: Cyclotron]. 1958. L293-40. Archives of CAS, Beijing.

4 "Moments in a Century: The Operation of China's First Nuclear Reactor and Cyclotron" (百年瞬间丨中国第一座原子反应堆回旋加速器运转), CCTV.com, updated August 30, 2021, https://m.news.cctv.com/2021/08/29/ARTI2R2nhDiNBy2Rvi9gYyNR210829.shtml.

5 The Third Ministry of Machine Building of China was in charge of the nuclear industry.

guide technical work during site selection, construction, installation, and final adjustment of the device. In June 1958, 613 Project Office (613 工程处, also known as the Electronics Laboratory, CAS, or Lanzhou Electronics Laboratory) was established in Lanzhou (Wu 2016, 87). Luo Xianhe 罗先河, Shen Qinghe 申青鹤, and others[6] were keys members of the office, and the cyclotron group of the Lanzhou Physics Study Office (predecessor of the Institute of Modern Physics of CAS) also contributed to it. The Soviet Union mainly provided the cyclotron construction technology, including the design, manufacture, and installation of the cyclotron's components, as well as the design and construction of the infrastructure.

In terms of the design and construction of the cyclotron, China was highly dependent on the Soviet Union. According to their agreement, the infrastructure design and equipment for the cyclotron would be provided by the Soviet Union. On November 19, 1958, the Central Atomic Energy Utilization Board of the Council of Ministers of the Union of Soviet Socialist Republics (USSR) (the general supplier) and the Soviet Union Technical Industrial Export Corporation (全苏技术工业出口公司) officially signed a contract with the Second Ministry of Machine Building of the PRC and China National Technical Import Corporation. The contract stipulated that the general supplier would provide the general ordering party with the equipment for the u-151-1 cyclotron from 1958 to the third quarter of 1959, and that the cost of the equipment and materials was initially estimated to be 8.7 million rubles.[7] On December 26, the Agreement on the Delivery of Equipment and Materials of the U-151-1

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6 Luo Xianhe 罗先河, deputy director of Office of the Northwest Branch of CAS and director of the Preparatory Office of the Electronics Section, CAS, was responsible for personnel affairs and works of experts in the 613 Project Office. Shen Qinghe 申青鹤, transferred from the Beijing Institute of Atomic Energy to the Lanzhou Physics Study Office in June 1958, was in charge of liaison with experts in cyclotron technology. Zhang Enhou 张恩厚, transferred from the Beijing Institute of Physics to the Lanzhou Physics Study Office in 1957, was appointed as the leader of the cyclotron group. Ye Meiling 叶美玲, a leading technician in Project 613 who had participated in the construction of the Cockcroft-Walton accelerator, was also transferred from the Beijing Institute of Physics to the Lanzhou Physics Study Office in 1957 (Wu 2016, 42, 45, 63; Wu, oral interview, May 2, 2018).

7 "Gongchengke Lanzhou Wulishi youguan 613 Gongcheng xiangmu shebei, cailiao ji tuzhi qingdan" 工程科兰州物理室有关 613 工程项目设备、材料及图纸清单 [List of Equipment, Materials, and Drawings Related to Project 613 in the Lanzhou Physics Study Office, Engineering Section]. 1958. L293-14. Archives of CAS, Beijing.

Lanzhou Electronics Laboratory. 1960. "Lanzhou Dianzishi guanyu 613 Gongcheng Sufang gongying cailiao jihua mingxi biao ji guonei shebeijian caigou" 兰州电子室关于 613 工程苏方供应设备材料计划明细表及国内设备件采购 [On the Plan Details of Soviet Supplied Equipment and Materials and Domestic Equipment Components Procurement for Project 613 of the Lanzhou Electronics Laboratory]. L293-87. Archives of CAS, Beijing.

Cyclotron (y−151−1 型迴旋加速器设备材料分交协定书) was signed. The attached List of Equipment and Materials for the Supply of the Cyclotron by the General Supplier (总供货方供应迴旋加速器装置的设备和材料清单) included the main manufacturing equipment, power supply system equipment, auxiliary manufacturing equipment, electrical equipment, and others items provided by the Soviet Union, among which the main manufacturing equipment largely covered the most crucial components for the cyclotron.[8]

The "delivery list of equipment" for the cyclotron drawn up was divided into three main categories: (1) equipment to be supplied by the Soviet Union; (2) design drawings to be supplied by the Soviet Union with the actual equipment to be supplied domestically; (3) equipment to be supplied domestically.[9] In consideration of the need to save foreign exchange reserves, the Chinese side planned to rely as much as possible on its own domestic industry to produce some of the equipment for the cyclotron, and the leader of the Lanzhou Laboratory, Yang Chengzhong 杨澄中, and other Chinese scientists hoped through the construction to acquire the technology to meet subsequent needs (Wu Enjiu, oral interview, May 2, 2018).[10] However, in subsequent negotiations on the supply of cyclotron equipment, in view of the difficulty in producing apparatus that required such high levels of precision, China repeatedly proposed that some items to be supplied by China as planned should be produced by the Soviet side instead.[11] China also made several requests for additional equipment to be provided by the Soviet Union after confirmation of the delivery list.[12] From this, it is evident that the Chinese

8 "Gongchengke Lanzhou Wulishi youguan 613 Gongcheng xiangmu shebei, cailiao ji tuzhi qingdan." 1958. L293-14. Archives of CAS, Beijing.

9 Lanzhou Electronics Laboratory. 1957. "Lanzhou Dianzishi guanyu 613 Gongcheng choubei xiaozu huiyi jilu." 兰州电子室关于 613 工程筹备小组会议记录 [Meeting Minutes of the Lanzhou Electronics Laboratory concerning Project 613 Preparation Group]. L293-5. Archives of CAS, Beijing.

10 "Wulishi guanyu qicai dinghuo yu Beijing Wulisuo fenjia qingdan" 物理室关于器材订货，与北京物理所分家清单 [Equipment Order List of the Lanzhou Physics Study Office and the List of (Items) on the Separation from the Beijing Institute of Physics]. 1957. L293-6. Archives of CAS, Beijing.

11 Lanzhou Electronics Laboratory. 1957. "Lanzhou Dianzishi guanyu 613 Gongcheng choubei xiaozu huiyi jilu" 兰州电子室关于 613 工程筹备小组会议记录 [Meeting Minutes of the Lanzhou Electronics Laboratory concerning Project 613 Preparation Group]. L293-5. Archives of CAS, Beijing.

12 Under the contract, apart from Soviet supplies, about 3500 cyclotron components were to be supplied by China. See Preparatory Office of the Electronics Laboratory, CAS 中国科学院电子实验室筹备处. 1960. "Yi jidu gongzuo qingkuang jianbao" 一季度工作情况简报 [Work Briefing of the First Quarter]. L293-73. Archives of CAS, Beijing. See also Lanzhou Electronics Laboratory. 1960. "Lanzhou Dianzishi guanyu 613 Gongcheng Sufang gongying cailiao jihua mingxi biao ji guonei shebeijian caigou." L293-87. Archives of CAS, Beijing.

side relied heavily on the Soviets for the supply of equipment for the cyclotron.

The engineering team of the Second Ministry of Machine Building was mainly responsible for the construction of the Lanzhou cyclotron,[13] including the installation and adjustment of the device. However, it required the help of Soviet experts. On January 18, 1959, Liu Wei 刘伟 (1916–1998), vice minister of the Second Ministry of Machine Building, wrote to the Soviet Union Representative Office in China expressing the hope that the Soviet Union would send experts to provide technical assistance in the installation, adjustment, and production of the equipment. On February 16, Polyakov, director of the External Supply Bureau of the Central Atomic Energy Utilization Board of the Council of Ministers of the USSR, replied, agreeing to dispatch ten Soviet experts.[14] In addition, in May, Gusev and Izhetschikov from the Leningrad Design Institute came to Lanzhou to inspect construction. They made suggestions, answered questions, revised design drawings, and gave lectures to technicians.[15] In late 1959, the infrastructure for Project 613 was almost completed, and a batch of Soviet machines arrived in China.[16] From September 1959 to March 1960, with the exception of one electrical engineer, Bersheyev, who was originally included in the contract, the other nine Soviet experts arrived in Lanzhou to participate in Project 613 (see Table 1).

In fact, the Soviet experts involved in Project 613 were all engineering technicians rather than physicists, and they were responsible for guiding the construction of the cyclotron and its infrastructure. Based on their professional knowledge and experience in previous projects, the experts gave valuable advice.[17] For instance, while inspecting the project, Gusev found that a crack in the protective wall extended into the corridor, raising the possibility that technicians in the corridor might be exposed to excessive

13 In February 1958, the Third Ministry of Machine Building was renamed the Second Ministry of Machine Building (Party Literature Research Center of the CPC Central Committee 1997, 605).

14 "Erjibu, Dianzishi guanyu gongzuo jihua, zongjie, jiedai waibin gongzuo gaikuang" 二机部、电子室关于工作计划、总结、接待外宾工作概况 [A Brief Introduction to the Work Plan, Work Summary, and Reception of Foreign Guests by the Second Ministry of Machine Building and Lanzhou Electronics Laboratory]. 1959. L293-76. Archives of CAS, Beijing.

15 "Lanzhou Dianzishi guanyu zhuanjia jianyi zhixing qingkuang ji tanhua jilu" 兰州电子室关于专家建议执行情况及谈话记录 [Notes on the Implementation of Recommendations of Experts and Conversation Records by the Lanzhou Electronics Laboratory]. 1960. L293-81. Archives of CAS, Beijing.

16 Lanzhou Electronics Laboratory. 1959. "Lanzhou Dianzishi 1959 nian gongzuo yaodian, jihua, zongjie, guanli zhidu huibian deng" 兰州电子室 1959 年工作要点、计划、总结、管理制度汇编等 [Compilation of Main Points, Plans, Summaries, and Management Systems on the Works of the Lanzhou Electronics Laboratory in 1959]. L293-46. Archives of CAS, Beijing.

17 In the "Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory," the Soviet expert Isakov mentioned that he had twenty-five years of work experience.

amounts of radiation. He suggested filling the crack with bricks with expansive properties. Gusev also warned that the possible sinking of the base of the main magnets could cause equipment to tilt and result in serious accidents, highlighting the special attention that should be paid to the infrastructure construction.

Table 1: Members of the Soviet experts team

Name	Job	Major	Responsibility in China	Date of arrival in China
Suslov Valentin Alekseevich (Суслов Валентин Алексеевич)	Chief engineer	Physical process engineering	Physical process adjustment (leader of the physical engineering team)	September 29, 1959
Andreev Alexander Andreevich (Андреев Александр Андреевич)	Technician	Mechanical engineering	Machinery installation (mechanics' leader)	January 26, 1960
Borisov Vitaly Dmitrievich (Борисов Виталий Дмитриевич)	Engineer	Magnetic field measurement engineering	Magnetic field measurement	March 1, 1960
Dmitryuk Georgy Ivanovich (Дмитрюк Георгий Иванович)	Technician	Vacuum engineering	Vacuum process piping installation and adjustment	March 11, 1960
Zotov Alexey Petrovich (Зотов Алексей Петрович)	Engineer in charge	Mechanical engineering	Machinery installation	September 29, 1959
Isakov Georgy Petrovy (Исаков Георгий Петровий)	Engineer in charge	Radio engineering	High frequency transmitter installation and adjustment	December 21, 1959
Kotlov Vladislav Mikhailovich (Котлов Владислав Михайлович)	Engineer	Electrical Engineering	Electrics installation	January 25, 1960
Stepanov Albert Vladimirovich (Степанов Альберт Владимирович)	Engineer in charge	Physical process engineering	Physical processes	February 11, 1960
Fedorov Vitaly Danilovich (Фёдоров Виталий Данилович)	Engineer in charge	Electrical engineering	Electrical instruments installation and adjustment	February 11, 1960

Source: Data from "Lanzhou Dianzishi Sulian zhuanjia dengjibiao" 兰州电子室苏联专家登记表 [Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory]. 1960. L293-77. Archives of CAS, Beijing.

The Chinese side accepted the proposals of the Soviet experts and asked the builders to follow their advice.[18] Nevertheless, differences of opinion emerged, and sometimes Chinese technicians or workers did not follow the recommendations of the Soviet experts.[19] Faced with such clashes, the Chinese leadership of the project almost always required Chinese personnel to respect the advice of the Soviet experts and to reach agreement as swiftly as possible.

The changing of Soviet designs also caused conflict between Chinese and Soviet personnel. When Gusev inspected the project, he found that many inserted equipment parts in the laboratory hall in the original design were missing, and the remaining ones were also misplaced against the Soviet drawing. The Chinese builders held the view that they should work according to the working drawings from the Chinese design institute, and they were not aware that it was necessary to report everything to the Soviet experts. Gusev complained that the Chinese side had modified the design without permission and demanded that construction be stopped immediately. The Chinese leadership of the project addressed the issue immediately, requiring that the Soviet design be followed. Soviet experts subsequently also provided detailed instructions on the methods of how to decide the locations of the inserted equipment parts.[20]

The above highlights China's absolute reliance on the Soviet Union both in the manufacture of equipment and the building of infrastructure in the process of construction of the Lanzhou cyclotron, and demonstrates that the mode of the cooperation between Soviet and Chinese engineers can be described as one of expert-student. The Chinese leadership of the project supported the Soviet experts' suggestions unconditionally, as was reasonable. The Soviet Union had long experience in the construction of cyclotrons. The first cyclotron had begun operation at the Radium Institute in Leningrad in 1937 (Kojevnikov 2004, 128). In 1939, the construction of the large cyclotron in Leningrad was resumed, its completion expected by the end of 1941, though the construction was actually completed after the end of World War II. The Soviet government also had approved funds for another large cyclotron in Moscow in

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18 "Lanzhou Dianzishi guanyu Sulian zhuanjia wei 613 Gongcheng tichu de jianyi" 兰州电子室关于苏联专家为 613 工程提出的建议 [Recommendations of Soviet Experts on Project 613 Compiled by the Lanzhou Electronics Laboratory]. 1959. L293-90. Archives of CAS, Beijing.

19 "Lanzhou Dianzishi guanyu Sulian zhuanjia wei 613 Gongcheng tichu de jianyi." 1959. L293-90. Archives of CAS, Beijing.

"613 Gongcheng zhihuibu huiyi jilu, gaopin hexin xiaozu huiyi jilu" 613 工程指挥部会议记录，高频核心小组会议记录 [Meeting Minutes of Project 613 Command and Those of the High Frequency Core Group]. 1960. L293-91. Archives of CAS, Beijing.

20 "Lanzhou Dianzishi guanyu Sulian zhuanjia wei 613 Gongcheng tichu de jianyi." 1959. L293-90. Archives of CAS, Beijing.

1941, which was supposed to have become operational in 1943 (Kojevnikov 2004, 133–134). In 1944 and 1946, two cyclotrons were built in Moscow (Zinovieva 2007). In 1944, Vladimir Veksler (1907–1965) published his proposal for a new method of particle acceleration, automatic phase stabilization, which after the war allowed physicists to build an entire new generation of particle accelerators (Kojevnikov 2004, 139). The synchrocyclotron was successfully activated on schedule in the Soviet Union in 1949. In 1957, a synchrophasotron began operation in Dubna (Zinovieva 2007). On the Chinese side, construction began on the first cyclotron in 1958 with the aid of the Soviet Union, so it is fair to say that the Chinese had no experience at all. The case mentioned above concerning the placement of inserted equipment parts shows that Chinese engineers were not able to understand the theory behind the Soviet design. Thus, strictly following the instructions of the Soviet experts was the most and realistic attitude for the leaders of the projects to take.

Nevertheless, the mode of cooperation in the construction still should not be regarded simply as one of the receipt of a big, ready-made device. Chinese engineers improved some tools for manufacturing and transporting equipment.[21] More than this, through the construction process engineering management was improved according to the Soviets' standards, and in order to provide the materials and to manufacture the components based on such strict demands for the cyclotron, the standards of manufacture in China were also improved greatly (Su 2019, 56–59).

4 Soviet engineers' interaction with the Sino-Soviet split

In the early 1960s, the relationship between China and the Soviet Union broke down, one major outcome being the withdrawal of experts by the Soviets.[22] On July 16, 1960, Sudalikov, minister-counsellor of the Soviet Embassy in China, presented a diplomatic note (hereafter referred to as "Note")[23] to Zhang Hanfu 章汉夫 (1906–1972), vice minister of Foreign Affairs of China. The Note announced that the Soviet government had decided to withdraw all experts and advisers (Zhang et al. 2004). On July 31, the Ministry of Foreign Affairs of China gave a note in reply to the Soviet Embassy. On August 1, the State Council of China issued a document on arranging the withdrawal of Soviet experts.

In early August 1960, the chief officer in charge of advanced science at the Soviet Embassy in Beijing called Suslov, head of the Soviet Experts Team of Project 613, and

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21 Preparatory Office of the Electronics Laboratory, CAS. 1960. "Yi jidu gongzuo qingkuang jianbao." L293-73. Archives of CAS, Beijing.

22 For the breakdown of the relationship between the Soviet Union and the PRC, see Whiting (2008, 478–538).

23 For details of the Note, see Chen (1996, 249–250).

required him and his colleagues to withdraw from Lanzhou, taking all the technical data with them. This meant that there was little time left for the Soviet specialists to continue their work in China. The Lanzhou Electronics Laboratory formulated an urgent work plan on bidding farewell to the Soviet experts, and arranged for the technicians to seize the chance to learn about the installation and adjustment technology of the cyclotron from the experts prior to their departure on August 14.[24] Chinese technicians were deployed to study and absorb all they could of the Soviet technical data and design drawings (Wu, oral interview, May 2, 2018). In this context, the attitude of the Soviet experts toward the Note was crucial to the construction of the cyclotron. In a document entitled "Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory," the Chinese side gave an evaluation of the work of each expert and their reactions to the announcement of the Note. As this information is very important for our further analysis and understanding of the international transmission of technology in a political context, we translate part of the text below:

Table 2: Record of each Soviet expert on the "Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory"

Name of the Soviet expert	Record in the "Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory"
Kotlov	He was surprised after reading the diplomatic note, and he works harder than before. He thought that he would let the Chinese people down and it would be a pity if he returned without finishing his work. On the train to Beijing from Lanzhou, he said: "Whether we will come back to China again is decided at a high level, and that is the government's affair." He believed that the problem would be solved, and he would be happy to come to our country again to help us.[25]
Fedorov	After reading the Note, he worked harder than before, but had no comment on this affair.[26]
Andreev	Our relationship has been very good, and his attitude toward returning to their country is that he would follow the others.[27]
Borisov	He never expressed any opinion with regard to politics.[28] He worked meticulously, patiently, and responsibly. He left documents to us and was concerned about our future work.[29]

24 "Guanyu songbie fanguo Sulian zhuanjia gongzuo jihua" 关于送别返国苏联专家工作计划 [Work Plan on Sending off Soviet Experts]. 1960. L293-76. Archives of CAS, Beijing.

25 "读过照会后，他感到很突然，工作比以前更加紧张了。他认为未完成就回国了，这与中国人民对他们的友谊和期望不相符，很遗憾。他在由兰州到北京的火车上讲：我们是否再来中国，这是上面的、政府的事，他相信是会很好解决的，但不是目前一下子可以解决的，他本人愿意再来我国帮助我们。"

26 "读过照会后，工作抓的更紧了，但是对此未表示什么态度。"

27 "我们的关系一直很好，对这次回国的态度采取随大流做法。"

28 "在政治上从不发表意见。"

29 "工作细致，耐心，负责。临走前把资料交出。对我们的今后工作比较关心。"

Continued

Name of the Soviet expert	Record in the "Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory"
Dmitryuk	After listening to the announcement of the Note, he refused to talk about political affairs. He said that "I work on technology, and I work according to my conscience." He stopped calling us comrades, using "dear friends" instead.[30]
Zotov	After listening to the announcement of the Note, he never mentioned this affair. He stopped calling us comrades, never talked about the friendship between the people of our two countries, and he even neither want to take photos with us nor give us his address.[31] Before the announcement of the Note, he had worked conscientiously and responsibly both in theoretical and practical areas, and he had also been concerned about the training of our cadres. In general, he would take our suggestions into consideration. After listening to the announcement of the Note, he did not work as conscientiously as before.[32]
Isakov	He worked actively, carefully, and meticulously. He took an active role in assigning the working plan. Especially during his last period in China, he worked harder than before. Before returning to his country, he explained the work to be done in the future in a very detailed way to us.[33] He thought that the Note was the business of those high up, that the problem could be solved soon, and that we could meet soon. He said: "Our political system is the same. No matter what happens, there will not be big conflict."[34] In the farewell feast held by our province, he said: "No matter what happens at the national level, I will teach all my knowledge to young Chinese specialists, and I consider this to be my duty."[35] He repeatedly said this before his departure: "It is the first time in my twenty-five year career that I have not completed the test of a transmitter within eight months." He felt very sorry about that, but believed that Chinese comrades could finish the remaining work.[36]

30 "听完照会后，坚决不谈政治，说我是做技术的，凭良心工作，不再称我们为同志，而是亲爱的朋友。"

31 "听完照会后，对此事一字不谈，对我们不再称同志，不再讲两国人民友谊如何，不愿和我们拍照和留下自己地址。"

32 "在宣读照会之前，工作一贯认真负责，理论实际都有，关心对我们干部的培养，一般还能顾虑我们的意见，听完照会以后，工作不如以前积极。"

33 "工作积极主动，认真细致，主动安排工作计划，特别是后一期，工作抓的很紧，临回国之前对下一步工作交待的很详细。"

34 "认为照会是上面的事情，很快可以解决，我们很快就会见面，他说：'我们的社会制度是一致的，不管怎样不会有大的冲突。'"

35 "在我省举行的欢送宴会上，他说：'不管国家如何，我都将把我的全部知识教给中国的青年专家，这是我的责任。'"

36 "他还在走之前不止一次的讲：'八个月的时间内没有调好一台发射机这还是我 25 年工作以来的第一次，'他很难过，但是他相信中国同志自己是可以把剩下的工作做完的。"

Continued

Name of the Soviet expert	Record in the "Soviet Experts' Registration Forms of the Lanzhou Electronics Laboratory"
Suslov	He always worked conscientiously, responsibly, and actively. He attended the site every day to inspect work. He gave advice immediately when he found any problems, and he was also straightforward in giving suggestions. He gave advice to the leaders of the project more than once, asking them to improve construction organization and safety.[37] He was concerned about the political and economic life in our country. He inquired about everything he encountered, including the organization of our academy. He used to ask the translator to read headlines and some of the content of the *People's Daily* (*Renmin Ribao* 人民日报) and *Gansu Daily* (*Gansu Ribao* 甘肃日报) to him, but he seldom expressed his opinion.[38] After the announcement of the Note, he worked harder than before. He frequently held meeting with experts, and he discussed more with them during work, but he did not express any attitude to the Note. Before leaving, he refused Minister Liu's invitation in Beijing to dine together.[39] Before leaving, our institution invited him to take souvenir photos, but he refused. On the way to the train station from the Beijing Hotel, he told Director Luo in the car: "I hope that you will not put those scrap rings under that gate while we are absent, as this will bring undue losses." These were his last parting words.[40]

Source: Data from "Lanzhou Dianzishi Sulian zhuanjia dengjibiao." L293-77. 1960. Archives of CAS, Beijing.

Soviet experts in Project 613 had different reactions to their government's decision. From the materials above we can see that among nine of them, at least four worked even harder than before the announcement of the Note. Beside this, even though Borisov's working state after the Note was not evaluated, he left technical documents to the Chinese. Only one of them (Zotov) became less active in his work. We can also see that at least two of them tried to adjust the relationship between themselves and their Chinese colleagues from the political to the personal, from "comrades" to "dear friends." We can better understand their responses through an analysis of the multiple roles that they played in the affair.

Each expert had at least three roles to play here. First, he was a Soviet citizen or even a member of the Communist Party of the Soviet Union (CPSU), thus had to be obedient to the Soviet government, as well as loyal to the party. Second, he was an

37 "工作一贯认真负责，主动，每天深入现场检查工作，发现问题立即提出意见，提意见也是比较坦率的，他不止一次向领导提出意见，改进施工组织和生活安全状况。"

38 "很关心我国政治、经济生活，经常见什么就问什么，如我院的组织形式等。常叫翻译把《人民日报》或《甘肃日报》上的重大标题和基本内容读给他听，但是发表见解不多。"

39 "读了照会以后，他的工作抓的更紧了，经常与专家们开会，和专家们在工作中商量也多了，但是对照会没有表示态度。当走之前，在北京刘部长请他吃饭时，他老是借故拒绝。"

40 "在走之前，我单位请他拍照留念，他好会拒绝。但在离北京宾馆列车站的路上，他在车子内与罗主任讲，我希望你们不要在我们不在的时候，把那几个废座圈用在园门之下，这将造成不应有的损失，这是最后的赠言。"

engineer, for whom completing his engineering project to the best of his ability was his duty. Thirdly, he was a human being, so the wish to return a favor to the Chinese, who always respected them and saw to their needs well, was a natural feeling. Before the Note was announced, completing the construction of the cyclotron would have fulfilled the responsibility of these three roles simultaneously, while conflicts between these roles manifested after the announcement. Their differing reactions can be explained based on how they personally prioritized their different roles.

For most of them, the role of engineer clearly assumed the highest priority, as they still worked hard even after their government had ordered them to cease their work in China. Dmitryuk stressed his role as an engineer and that he worked according to his conscience. Nevertheless, at least three of them (Dmitryuk, Zotov, and Suslov) reacted in what can be construed as a political way, including refusing to attend affairs that had no connection with their engineering work, such as a farewell dinner, and not calling their Chinese colleagues "comrades." One of them (Zotov) even put less energy into his work. For them, their identities as Soviet citizens or party members also held an important place. On the other hand, two of them (Kotlov and Isakov) directly expressed that they took responsibility for the friendship they had with Chinese people, or Chinese colleagues. To transfer knowledge and to help the Chinese in finishing the construction of cyclotron was their way to fulfill this responsibility. Dmitryuk only addressed his Chinese colleagues as "dear friends" rather than "comrades," which shows that he was sensitive about the political situation, but still preserved personal feelings toward his Chinese colleagues. Thus, the high position occupied by personal feelings may also explain the reactions of some Soviet experts towards the Note and the Sino-Soviet split.

The case of Suslov deserves further analysis. Suslov had one more role than the others, as he was the leader of the group of experts in Project 613. The Chinese side gave a very positive evaluation of his work and his attitude toward work from the beginning, yet at the same time he was concerned about the local political situation. After the Note had been issued, the Soviet Embassy in Beijing called him directly about the withdrawal. Thus, his responsibility changed from finishing the construction of the cyclotron to organizing the withdrawal of the experts and making sure that they obeyed the order from the Soviet government, including bringing back the technical materials and designs, or in other words, not giving them to the Chinese. Suslov performed his duty, as, according to Chinese physicist Wu Enjiu, he prevented other experts from handing over special precision meters and related information to the Chinese side (Wu 2016, 89). After he had been informed about the content of the Note, he cut off his personal relationships with his Chinese colleagues and leaders, not accepting any personal or formal invitations and refusing to take photos together. Up to this point, we may say that he had performed his roles as a Soviet citizen and a party member wonderfully, as well as the leadership of the group. Further investigation, however, shows us that his case was not that simple. As he worked even harder than before the Note was announced, having already worked very hard, inspecting the work and visiting the site every day, we can imagine his working situation. Even though he prevented the others from leaving materials to Chinese, at the very last moment, on his way to the train station from the Beijing Hotel, he advised his Chinese colleague not to take a specific step in the construction, as in his mind this step would bring some aspect of loss to the project. And he took this as his final piece of advice. We may suppose that this problem had been bothering him, and he could not prevent himself from mentioning it. This shows us that how eagerly he wanted to fulfill his responsibility as an engineer. Generally speaking, the roles of citizen of the Soviet Union and engineer were of equal importance to him, but he stressed his personal feeling toward his colleagues at large. Nevertheless, the two conflicting roles lead to his contradictory reactions to the Note.

After the Soviet experts returned home, the suggestions they had made in July–August 1960 were adopted by the Chinese side in the subsequent installation and adjustment of the cyclotron and continued to be of importance. For example, in 1963, the 613 Project Office drew up the External Target Adjustment Plan for the U-150-1 Cyclotron, in which the operating voltage of the deflector plate was determined following the suggestion of Fedorov. He stated that the voltage of the deflector plate could be increased to about 70–80 kV at most, and that it would be very difficult to make it higher. Similarly, the stability of the electromagnetic lens and deflecting magnet was determined based on the advice of Borisov, who had said that their degree of stability should be 0.5% and 0.1%, respectively.[41]

In summary, transnational transmission is inevitably shaped by the political context, especially when the knowledge involved has a crucial military application, just as in the case we have analyzed in this paper. The dramatic change of the Sino-Soviet relationship caused the conflict in the roles of the Soviet scientists and engineers who worked in China, yet their sense of professional responsibility remained their highest priority, which guaranteed the completion of the construction of Lanzhou cyclotron.

5 The Chinese people completed the construction of the cyclotron

By August 1960, when the Soviet experts left Lanzhou, the infrastructure for the 1.5 m cyclotron had been basically completed, nearly 60% of the equipment installation had been finished, and 20% of the individual adjustments had been accomplished, but comprehensive adjustments had not yet begun. From this time on, the Soviet Union

41 Lanzhou Institute of Modern Physics. 1963. "y-150-1 xing huixuan jiasuqi waiba tiaozheng fangan" y-150-1 型迴旋加速器外靶调整方案 [External Target Adjustment Plan for the U-150-1 Cyclotron]. L293-152. Archives of CAS, Beijing.

ceased to provide equipment and design drawings, of which there had been more than three hundred items of over seventy categories. Mechanical vacuum pumps, magneto-resistors, and other essential facilities had not been provided, some of which could not be produced by China at the time (Wu 2016, 88).[42] In addition, as most cooperation work was left half completed, the construction team of Project 613 were assigned to other projects. Only a few workers and technicians of the Second Ministry of Machine Building remained in Project 613. With only twenty-odd university graduates, the project office was in desperate need of improvement in technical skills and experience. Faced with a "half-completed project" with plenty of unsolved difficulties, would the Chinese side choose to give it up or proceed to finish it?

At this critical juncture, the Second Ministry of Machine Building decided to continue the construction of the project. Liu Wei, vice minister of the Second Ministry of Machine Building, came to the site and challenged Chinese technicians to use their ingenuity to build the cyclotron on their own (Wu 2016, 89).[43] As a result, the Second Ministry of Machine Building redeployed scientists and engineering technicians to take part.

In February 1961, the Beijing Institute of Atomic Energy held a meeting to discuss the organization of the project. The meeting decided that Wang Ganchang 王淦昌 (1907–1998) and Li Yi 力一 (1913–1996) would take charge of the medium-energy cyclotron and Project 613. Wang Ganchang was to be responsible for scientific research, Li Yi in charge of engineering (Ge 2013, 326). The Lanzhou Physics Study Office[44] assisted 613 Project Office in the construction of the cyclotron, and Office Director Yang Chengzhong 杨澄中 (1913–1987) (Figure 2) was appointed as the project's chief director

42 Lanzhou Physics Study Office. 1963. "Lanzhou Wulishi guanyu 613 Gongcheng 61 nian zhuyao gongzuo zongjie ji 62 nian gongzuo de chubu yijian" 兰州物理室关于 613 工程 61 年主要工作总结及 62 年工作的初步意见 [Summary of the Main Work of Project 613 in 1961 and Preliminary Views of the Work in 1962 by the Lanzhou Physics Study Office]. L293-105. Archives of CAS, Beijing.

43 Lanzhou Physics Study Office. 1963. "Lanzhou Wulishi guanyu 613 Gongcheng 61 nian zhuyao gongzuo zongjie ji 62 nian gongzuo de chubu yijian." L293-105. Archives of CAS, Beijing.

44 In early 1962, by mutual agreement between CAS and the Second Ministry of Machine Building, the atomic energy department of the Lanzhou Physics Study Office, CAS was merged with the 613 Project Office to form the "Institute of Modern Physics, CAS" (located in Lanzhou), code named the "Northwest 203 Institute." The institute was under the dual leadership of the Second Ministry of Machine Building and CAS. The directorship of the institute was vacant, and Yang Chengzhong and Zhang Yumin 张裕民 were assigned as deputy-directors. See "Zhongkeyuan Jindai Wuli Yanjiusuo jiankuang" 中科院近代物理研究所简况 [A Brief Introduction to the Institute of Modern Physics, CAS]. 1964. L293-197. Archives of CAS, Beijing.

(Wu 2016, 88).[45]

Yang Chengzhong had studied in the United Kingdom, receiving a doctorate from the University of Liverpool in 1950. During his studies in England, he discovered the deuteron and proton stripping reaction with John Riley Holt (1918–2009) and others,[46] and participated in the development of nuclear physics experimental equipment, including electrostatic accelerators, differential ionization chambers, magnetic ion sources, and others. In 1951, Yang returned to China. He worked at the Institute of Modern Physics, CAS in Beijing (predecessor of the Institute of High Energy Physics, CAS). In 1953, he directed the construction of the 700 kV proton electrostatic accelerator with Zhao Zhongyao 赵忠尧 (1902–1998), and in 1957 he directed and participated in the construction of the 400 kV high voltage multiplier at the Lanzhou Physics Study Office.[47] In addition, he contributed to the development of scintillation detectors for atomic nuclear physics experiments, as well as linear amplifiers, counters, and other nuclear electronics instruments (Qian and Zhu 1987, 182). It is thus fair to say that Yang was a highly qualified physicist with considerable experience in the construction of scientific instruments.

Figure 2: Yang Chengzhong (1913–1987). Courtesy of the Institute of Modern Physics, CAS.

As the leader of the Laboratory of Physics in Lanzhou, Yang had followed the process of the construction of the cyclotron attentively from the beginning and played an important role in determining the "delivery list of equipment." Under his leadership,

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45 Yang, Chengzhong. 1983. "Zhongguo Kexueyuan Jindai Wuli Yanjiusuo jiansuo yilai keyan gongzuo zongjie (1957–1983)" 中国科学院近代物理研究所建所以来科研工作总结（1957～1983）[Summary of Scientific Work of the Institute of Modern Physics, CAS (1957–1983)]. R009-F-00005. Archives of CAS, Beijing.

Preparatory Office of the Lanzhou Electronics Laboratory, CAS 中国科学院兰州分院电子实验室筹备处. 1959. "Yinianlai zhuanjia gongzuo zongjie" 一年来专家工作总结 [Summary of the Experts' Work during This Year]. L293-76. Archives of CAS, Beijing.

46 "Yang Chengzhong suo congshi, zhidao canyu de keyan gongzuo" 杨澄中所从事、指导参与的科研工作 [Scientific Work Yang Chengzhong Engaged in and Supervised]. 2012. R009-A-000024. Archives of CAS, Beijing.

47 "Zhongguo Kexueyuan xuebu weiyuan houxuanren tuijianshu" 中国科学院学部委员候选人推荐书 [Recommendation of Candidates for Academicians of CAS]. 1979. R009-A-00003. Archives of CAS, Beijing.

the Chinese construction team used the technology provided by the Soviet Union and adopted some new approaches to solve the remaining technical problems based on available technical and personnel conditions. A typical case was the construction of the protection door of the main hall.

The main hall of the cyclotron laboratory required a protection door. It was not only an important component for radiation protection, but also a passage for transporting magnets and other large equipment. In accordance with the design provided by the Soviet experts, it should be a vertical lift door, consisting of two reinforced concrete slabs 4.4 meters wide, 3.5 meters high, 1.3 meters thick, and weighing 100 tons, suspended from a large shaft by two wire cables with a diameter of 47.5 mm (Wu 2016, 90). Prior to the withdrawal of the Soviet experts, the construction of the door had already become a technical obstacle for the Chinese side. In December 1959, Soviet experts stressed that the design drawings of the protection door had not arrived, drastically affecting the progress of Project 613.[48] In fact, the Chinese side followed the Soviet design principles, but had some concerns about the technical and equipment conditions, as well as potential safety risks.[49]

Wire cables, electric motors, bearings, and other components with customized specifications were needed in the construction of the protection door. Since the Soviet experts already returned home, China had to be self-reliant. Under these circumstances, some Chinese nuclear physicists and engineers from the 613 Project Office, the Laboratory of Physics in Lanzhou, CAS Institute of Atomic Energy and the Second Ministry of Machine Building cooperated to provide a new design.[50]

Different from the vertical lifting concrete door, the newly designed protection door can be described as a movable water door. It employed water as the radiation shielding material. This was a design that was actually already commonly used by many nuclear physicists. A young physicist who took part in Project 613, Wu Enjiu,[51] still

48 Preparatory Office of the Lanzhou Electronics Laboratory, CAS. 1959. "Yinianlai zhuanjia gongzuo zongjie." L293-76. Archives of CAS, Beijing.

49 The Chinese technicians were concerned that "if the wire cables broke and the door fell, it would cause tremendous damage to the cyclotron and the entire building" (Wu 2016, 90). "一旦钢丝绳断裂，大门跌落，会给加速器和整个建筑带来损害。"

50 Lanzhou Physics Study Office. 1963. "Lanzhou Wulishi guanyu 613 Gongcheng 61 nian zhuyao gongzuo zongjie ji 62 nian gongzuo de chubu yijian." L293-105. Archives of CAS, Beijing.

51 Wu Enjiu 邬恩九 (1934–), from Hunan Province, is an experimental nuclear physicist. He graduated from Wuhan University in 1953 and worked at the Institute of Modern Physics, CAS (Beijing) after graduation. Then he was transferred to the Lanzhou Physics Study Office, engaging in experimental nuclear physics research. Following the withdrawal of the Soviet experts, Wu participated in the construction of the Lanzhou cyclotron, working on beam tuning and other missions related to experimental research.

remembered the theory and the design clearly:

> Neutron rays, gamma rays, and soft x-rays were released from the cyclotron, so it was necessary to protect ourselves from neutrons and gamma rays. Concrete was effective for shielding gamma rays by its mass since the protective effect was proportional to the mass. But concrete was deficient in shielding neutrons, while the most powerful neutron shielding material was hydrogen. Therefore, hydrogen or paraffin wax was the best choice.[52]
>
> Our idea was to shield neutrons in the water layer. Behind the water layer, an additional movable concrete layer served as another protective layer. Building a concrete layer was just like building a wall, and it was easy and fast as long as we precast many concrete blocks. In other words, instead of building a concrete wall as proposed by the Soviet Union, we came up with the idea of building a combined water gate and concrete gate. Neutrons could be slowed down and absorbed by water. The remaining gamma rays were blocked by the concrete layer (Wu, oral interview, July 21, 2021).[53]

The Chinese technicians took full advantage of available resources to construct the "water gate." They installed four wheels under a step-shaped tank with a volume of 32 cubic meters (Wu 2016, 90), and combined the water layer with the movable concrete layer to form the protection door.

> The water door was also movable, so we didn't need to hang it. Its movement could be readily achieved on the ground. And the concrete wall was built up by movable concrete blocks. We could tear the wall down if needed. If we want a thicker wall, just build more blocks (Wu, oral interview, July 21, 2021).[54]

Thus, engineering risks could be avoided. In terms of scientific principles, both the lifting concrete protection door[55] and movable water door were good solutions to the

52 "加速器出来有中子射线，也有 γ 射线，或者更软一点的 x 射线，而防护的对象最主要就是中子和 γ。混凝土对于 γ 射线是有效的，因为质量大，阻力也就大了。但是它对中子的防护是欠缺的，而中子最有效的防护材料就是氢元素。所以中子的防护最有效的是水，或者石蜡。"

53 "我们想的办法就是，对于中子让它在水里边解决，在水层后面，还有一层防护，就是活动的混凝土层。活动的混凝土层是人工就可以垒一扇墙，是很快的事情，做很多预制的混凝土砖。也就是说，苏联的一扇混凝土墙，我们把它解决成了水门和混凝土。水能把中子减速，减速之后中子变成慢中子被吸收，放出来的就是 γ 射线，γ 射线再用混凝土层阻挡。"

54 "水门也是活动的，不需要吊起来这么重。我们可以在地面上比较容易的解决它的移动问题。同时我们的混凝土的墙也是活动的混凝土垒起来。需要的时候就可以把它拆掉，不需要的时候就可以把它放在那个地方。如果要厚一些的话，那我就多垒一些混凝土砖就行了。"

55 The Soviet design plan also works for protection, as they insert material into the concrete to provide shielding against neutrons (Wu, oral interview, July 21, 2021).

radiation shielding challenge.[56] The water gate, without any complicated supporting equipment, was simple in construction. It was feasible under the technical conditions of China at that time. However, compared with the original design, the new design had the weakness of taking up too much space. The lifting door could protect against radiation with a concrete wall more than 1 meter thick, while the movable water gate included a water layer of more than 1 meter or even 2 meters and a concrete wall. In addition, the opening/closing of the door was not convenient. Nevertheless, the door was only opened once a year or even once every few years in actual situations. The construction and application of the cyclotron proved that the water gate was economical, reliable and fully met protection requirements (Wu, oral interview, July 21, 2021; Wu 2016, 90).

When adjusting the cyclotron, the beam tuning scheme was a key aspect. The Soviet experts had figured that the Chinese side could do the internal target beam tuning, but that the external one might be challenging (Wu 2016, 89). Based on Soviet experience and suggestions the experts had provided before their withdrawal,[57] the Chinese physicists completed the adjustment. The 613 Project Office referred to the *Summary Report on Beam Tuning of the Soviet 1.2-Meter Cyclotron* (苏联 1.2 米回旋加速器调束总结) from the Beijing Institute of Atomic Energy. The report reviewed and summarized how the institute had finished the adjustment of the 1.2-meter cyclotron with assistance from the Soviet Union.[58] The Chinese physicists also referred to the notes of two Soviet reports (*Technical Report on the Adjustment of the Cyclotron of the Institute of Physics, Ukrainian Academy of Sciences* [Технический отчёт наладка циклотронной установки ИФАН УССР]; and *Technical Report on the Benchmark Testing of the U-120-1 Cyclotron*

56 In the solution of the lifting protection door, neutron shielding can also be achieved by adding hydrogen, such as borax, to the concrete (Wu, oral interview, July 21, 2021).

57 Lanzhou Institute of Modern Physics. 1963. "y-150-1 xing huixuan jiasuqi waiba tiaozheng fangan." L293-152. Archives of CAS, Beijing.

58 Previously, the Lanzhou Institute of Modern Physics, CAS, wrote a letter to the Atomic Energy Institute, CAS (predecessor of China Institute of Atomic Energy), stating that "We would like to request you to lend us the original document of the *Summary Report on Beam Tuning of the Soviet 1.2-Meter Cyclotron* for a time. We will return it by the fourth quarter of this year. Other resources, including beam tuning experience of your institute and the bibliographical index of the cyclotron theory and operating phenomena, are also much needed. If you have available information and it is not convenient for you to send it, we can ask our staff in Beijing to copy it." (恳请你所将 201 的"苏联 1.2 米回旋加速器调束总结"原文本借与我们使用一个时间，于今年第四季度归还，其他有关资料，如你所的调束经验及回旋加速器理论和运行现象的文献索引等有关学术活动资料，也是我们非常需要的，如果你们在这方面有现成的资料，若不便寄来，我所可通知在京人员前去抄录。) See Institute of Modern Physics, CAS. 1962. "Wei qing jieyong huixuan jiasuqi youguan ziliao you" 为请借用回旋加速器有关资料由 [Information about Borrowing Documents about the Cyclotron]. L293-122. Archives of CAS, Beijing.

[Технический отчёт стендовые испытания циклотронной установки У-120-1]), in which experience of how to adjust a similar type of cyclotron was included.

Chinese scientists took initiatives while assimilating Soviet experience. They tapped expertise to formulate a realistic adjustment plan. Before tuning the beam, the Chinese scientists calculated that the values of the "central magnetic field for accelerating deuterium nuclei" and "energy extraction" on the Soviet drawings did not match when adjusting the main magnetic field. On the basis of calculations and their knowledge, Chinese scientists changed the value of the "central magnetic field" to correspond to the value of the "energy extraction," thus meeting the requirements of the project and ensuring that the Soviet-supplied modulating ring could be used without manufacturing a similar product in China.[59]

On September 28, 1963, Chinese scientists finally completed the overall beam tuning for Project 613. The beam intensity was 0.7 × 100 μA, which met and exceeded the design standard (0.3 × 100 μA), marking the successful construction of the 1.5-meter cyclotron (Figure 3).[60]

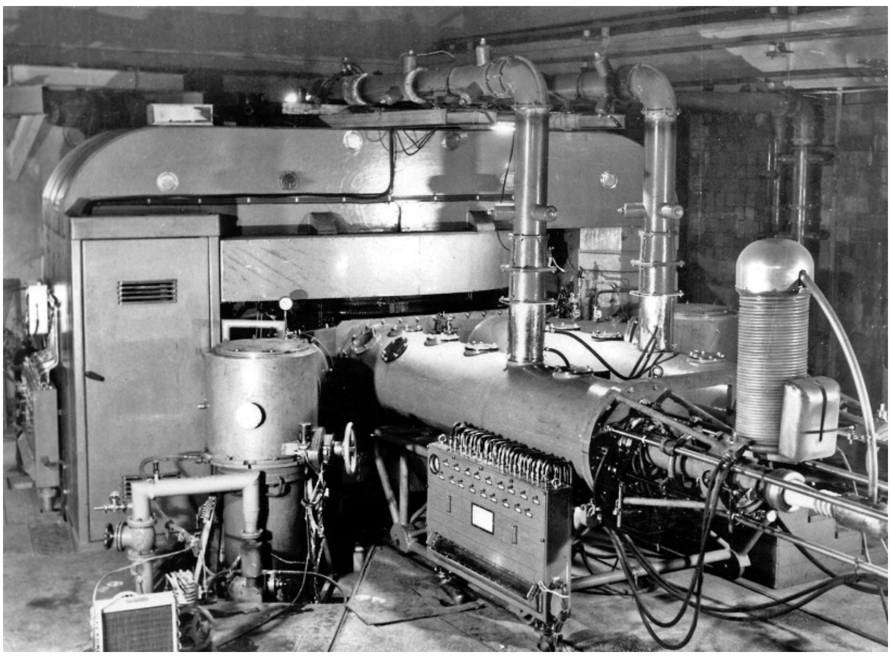

Figure 3: The 1.5-meter cyclotron. Courtesy of the Institute of Modern Physics, CAS.

59 Preparatory Office of the Electronics Laboratory, CAS 中国科学院电子实验室筹备处. 1961. "Baogao ceci jishu fangan" 报告测磁技术方案 [Report on the Magnetometry Plan]. L293-122. Archives of CAS, Beijing.

60 The Second Ministry of Machine Building. 1963. "Zhuhe 613 Gongcheng zongti tiaozheng gongzuo shengli jieshu" 祝贺 613 工程总体调整工作胜利结束 [Congratulations on the Successful Completion of the Adjustment of Project 613]. L293-152. Archives of CAS, Beijing.

After the cyclotron was put into operation in 1964, it was soon used in research related to the development of the hydrogen bomb. While undertaking national defense missions, scientists also carried out applied research with the cyclotron, including the preparation of artificial radioactive isotopes and others.[61] In the 1970s, scientists modified the cyclotron into one capable of accelerating three types of heavy ion, ^{12}C, ^{14}N, and ^{16}O, for basic research in heavy ion physics (Su 2019, 96–98).[62] In November 1976, a new plan proposed by Chinese scientists to build a large heavy ion cyclotron in Lanzhou was approved by the Chinese government, and the original 1.5-meter cyclotron was rebuilt as the injector in the new cyclotron's system (Su 2019, 145).[63] Since 1992, dozens of new nuclides have been synthesized on the heavy ion cyclotron in Lanzhou, constituting important achievements of Chinese scientists in heavy ion physics (Fan 1999, 350–351; Su 2019, 154–155).

6 Conclusion

It was in answer to the demands of the Chinese government's interest in nuclear technology that the Soviet government provided assistance for the construction of the Lanzhou cyclotron; in other words, the cyclotron's application in military technology was the crucial reason for its construction. China relied heavily on the Soviet Union both for the manufacture of equipment and the building of infrastructure in the process of the construction of the cyclotron. The Soviet experts involved in Project 613 were all engineering technicians rather than physicists, and the cooperation between Soviet and Chinese engineers can be described as in the mode of expert-student. In fact, at the time the Soviet Union had long experience in the construction of cyclotrons, while China had none. Thus, strictly following the instruction of Soviet experts was the most appropriate and realistic attitude for the leaders of the project to adopt. Nevertheless, cooperation in the construction could still not be regarded as simply the receipt of a ready-made, big device. Through its construction, engineering management and equipment manufacturing standards were greatly improved. The dramatic change in the Sino-Soviet relationship caused conflicts in the roles played by the Soviet engineers who worked in China. Each expert had at least three roles to play, and the differing

61 "1965 kexue yanjiu tongji nianbaobiao" 1965 科学研究统计年报表 [Annual Report of Scientific Research Statistics of 1965]. 1965. L293-204. Archives of CAS, Beijing.

"2 hao renwu" 2 号任务 [Task 2]. 1966. L293-398. Archives of CAS, Beijing.

62 "Wosuo sannianlai zhonglizi wuli yanjiu gongzuo huibao" 我所三年来重离子物理研究工作汇报 [Report on the Research Work on Heavy Ion Physics in Our Institute for Three Years]. 1974. HS12 4 7611-Y-4. Institute of Modern Physics, CAS Archive, Lanzhou.

63 "7611 Gongcheng jungong baogao" 7611 工程竣工报告 [Completion Report of Project 7611]. 1989. L293-474. Archives of CAS, Beijing.

reactions they had can be explained by how each personally prioritized these different roles. For most of them, the role of engineer took the highest priority, and this played an important part in the completion of the construction of cyclotron.

After the departure of the Soviet engineers, the Chinese government decided to continue Project 613 as the cyclotron was intimately related to military nuclear research. Chinese physicists played the leading role in the project, and through close cooperation with engineers and relying on the technological materials and instructions left by the Soviet engineers, the cyclotron was completed. During the process, the scientists overcame technical shortcomings by making full use of scientific principles. After completion, it was soon put into use in military research concerning the hydrogen bomb, and later with modification, was used as the main instrument for heavy ion physics research in China.

Project 613 spanned various historical stages of the Sino-Soviet relationship from collaboration to split, and thus can provide us with valuable clues for the understanding of transnational history of science and technology. Though there was an apparent unidirectional transmission from the Soviet Union to China, through detailed analysis, it becomes clear that both sides played a role in the shaping of the content and progress of the transmission. Even the transnational movement of knowledge is inevitably influenced by political factors from both sides, and the function of the realization of such influences is complicated, as we may see from the case of the construction of the Lanzhou cyclotron.

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