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The Emergence of Appropriate Technology: The Localization of German Krupp Artillery Technology in China (1866–1932)

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Abstract: China's change from traditional to modern military technology exerted a global impact, but the process was far from straightforward. During the late nineteenth and early twentieth centuries, while Western colonialism and economic globalization were sweeping across the globe, China, as a latecomer, embarked on the path of military industrialization. This led to the inevitable interweaving of East and West, tradition and modernity, and technological backwardness and industrial independence. The introduction and absorption of German Krupp artillery technology serves as a quintessential example. By procuring, emulating, and employing Krupp artillery products and technology, the late Qing dynasty swiftly established modernized armies, navies, and arsenals. Moreover, China's acceptance of Krupp's technology gave rise to new local technology that proved even more appropriate for its needs. The localized technology is referred to as "appropriate technology" in this article. This concept enables us to gain a better understanding of the continuity and discontinuity of relevant knowledge during the globalization process and its decisive influence on technology localization.
Keywords: Krupp, artillery, China, localization, appropriate technology

摘　要：中国的军事技术从传统向现代转型具有全球影响，过程曲折而漫长。19 下半叶至 20 世纪初，在西方殖民与经济全球化的浪潮中，中国以后进国家的姿态走上军事工业化之路。东方与西方、传统与现代、技术落后与工业自立，不可避免地交织在一起。引进与吸收德国克虏伯火炮技术是其中的一则典型案例。通过采购、仿造和使用克虏伯火炮的产品与技术，晚清快速建立起现代化的陆军、海军与兵工厂。在接受克虏伯技术时，新的本土

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技术常常表现得更适于转型的需求，因此本文称之为适用技术。借助它，或许可以更好地理解全球化进程中相关知识的连续与断裂，及其在技术本土化中的决定性影响。
关键词：克虏伯，火炮，中国，本土化，适用技术

In China, modern technology can be traced back to the localization of Western artifacts and their associated knowledge. One particular area where such localization occurred was China's artillery, which underwent a process of "Kruppization." This process was characterized by the Sino-German exchange of technology, knowledge, and culture, with arms trade, imitation manufacturing, and weapon utilization being the three main channels of interaction. These channels facilitated not only the flow of artifacts but also the movement of personnel. The inflow of artifacts into China played a key role in driving the emergence of the country's modern military and ordnance industry. Meanwhile, the transnational exchanges of personnel brought about a complex network consisting of figures such as Alfred Krupp, Li Hongzhang, Sino-German diplomats, foreign traders, missionaries, overseas students, new intellectuals, and soldiers, among others. This network was central to the transfer and localization of Krupp artillery technology in China.

During the late Qing period, Chinese imitations of Krupp artillery were commonly referred to as "Krupp-style" (*Keshi* 克式) guns. This terminology has been adopted in this article to refer to the localized Krupp technology that emerged in China.

1 Introduction: The globalization context of China's "Krupp-style" technology

For China, globalization during the nineteenth and twentieth centuries can be understood through the dynamic between impact and response. In the mid-nineteenth century, the flow of knowledge between China and the West was epitomized by "Western learning spreading to the East" (*Xi xue Dong jian* 西学东渐). The Chinese reception of Western knowledge far exceeded that during the visits of Jesuit missionaries to China around the seventeenth century. More than two hundred years after Matteo Ricci (1552–1610), it was no longer the interest of the court in astronomy or mechanical clocks, but rather the numerous wars that erupted within China, that provided the justification for the dissemination of Western knowledge to China. Following the First Opium War (1839–1842), the Second Opium War (1856–1860), and the Taiping Rebellion (1850–1864), the Qing dynasty experienced the pressing demand to upgrade its military technology. The so-called Group Advocating Self-Strengthening (*Yangwu pai* 洋务派) that emerged among officials and intellectuals pursued "learning the merits of the foreign" (*shi yi zhi changji* 师夷之长技), and the intellectual elites who sought change gained an increasingly prominent voice. John K. Fairbank (1907–1991) astutely encapsulated their shared traits as "recognition of China's need to know the West" and "the desire for Western technology" (Teng and Fairbank 1979, 23–131). In other words, some late Qing intellectuals recognized that China had ceased to be a producer of important technology, and should learn from the West. Using Fairbank's "psycho-ideological approach" to interpret this phenomenon, it is evident that the Chinese elites psychologically acknowledged themselves as learners of Western science and technology, stemming from their passive acceptance of the incompatibility between Western modernity and Confucian culture. In reality, the Group Advocating Self-Strengthening did not have the intention to overthrow the traditional order; instead, their primary focus was on initiating the Self-Strengthening Movement (1861–1895) with its elements of intellectual enlightenment and reform.

The desire of the Group Advocating Self-Strengthening for Western technology was largely simplified into achieving modernization of the Qing Empire's military. Topping the list of their must-learn technologies were the Western "fortified ships and powerful artillery" (*jianchuan lipao* 坚船利炮). In 1863, Li Hongzhang 李鸿章 (1823–1901) wrote to Zeng Guofan 曾国藩 (1811–1872), both key representatives of the Group Advocating Self-Strengthening, directly underscoring the significance of acquiring Western artifacts, technology, and knowledge: "If [the Chinese] firearms could match the Western counterparts . . . and acquire the secrets of Britain and France, we could gradually manufacture and utilize guns, artillery, and ships, eventually competing with Britain and France. If China doubles its care in this area, then in a hundred years we will be able to achieve national independence in this area of our strength" (Li 2008b, 271–278).[1] Li's ideas marked a significant departure from traditional cultural egocentrism (Chu and Liu 2016). In the following year, he submitted a proposal to the Office for the General Management of Affairs Concerning the Various Countries, proposing the "weapon-machine-talent" correlation as the key to acquiring knowledge of Western military industries. He believed that "If China aims to strengthen itself, it is imperative to learn from foreign weaponry. To learn from foreign weapons, China should seek to acquire the means of production and corresponding techniques rather than relying solely on foreign personnel. In the pursuit of the means of production and the experts who can produce them, China may consider establishing a dedicated examination system to recruit talents" (Li 2008f, 313).[2] For Li Hongzhang, the path to military industrialization lay in purchasing machines, manufacturing weapons, and employing talented individuals.

However, to fully comprehend China's military industrialization, it is imperative to

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1 "若火器能与西洋相埒……求得英法秘巧，枪炮轮船渐能制用，遂与英法相为雄长。中土若于此加意，百年之后，长可自立。"

2 "中国欲自强，则莫如学习外国利器。欲学习外国利器，则莫如觅制器之器，师其法而不必尽用其人。欲觅制器之器与制器之人，则或专设一科取士。"

place its causes and effects in a global context rather than viewing it as a purely domestic issue. Li Hongzhang and his contemporaries, who could not accurately gauge the problem of technology transfer brought about by global interactions, believed that the Qing Empire could rival Britain and France in power once it had mastered the same technology and industry as the West. Although the Self-Strengthening Movement seemed to be a choice of development path by local elites, Immanuel Wallerstein's (1930–2019) theory suggests that this movement was an inevitable outcome of a periphery country's integration into the modern world system and acceptance of a global division of labor (Chase-Dunn, Smith, Manning, and Grubacic 2020). Opponents of the movement, by using the term "Self-Strengthening" (*ziqiang* 自强), hoped that China could rely on itself to escape marginalization in the world. Unfortunately, as observed by G. H. Blakeslee (1871–1954),[3] the wars between the powers and China brought "ruthlessness and destruction" upon the latter (Blakeslee 1913, 42). The novel artillery, cruisers, and dozens of local arsenals purchased at great expense by Li Hongzhang and his contemporaries in 1895 could not spare the Qing army the fiasco of the Sino-Japanese War of 1894–1895. The attempts of the Group Advocating Self-Strengthening to break the existing "core-periphery" development path in the world were destined to be more challenging than anticipated. The Western world, along with the rising Japan, urgently demanded the contribution of Chinese resources to them, but did not intend to accept a Qing Empire with a potent military. Z. C. Beals (1901, 151–154), editor of *China Messenger* in 1901, explicitly conveyed this state of affairs: "Her immense coal fields and minerals of every kind await developing. Her forests will need the rotary saw instead of the slow hand saw; for as yet she has no other. Her harvests will demand the Western harvester and threshing machine, instead of the tedious hand work of today. And so in every industry there will be demands for all the latest and best machinery," and China's strong ships and powerful artillery "would be a curse to herself and a menace to mankind."

The topic of localization constitutes an unavoidable subject within the realm of global military history. In fact, it is not contradictory to globalization, but rather a part of it. The perspective of the "Great Divergence" is not suitable for analyzing localization. Regardless of whether it was the late Qing Empire or the Republic of China, both were swept up in the wave of globalization. Consequently, it is inappropriate to place them in the "Great Divergence" between China and the West. Kenneth Pomeranz (2003, i–vii), in the preface to the Chinese version of his work, provides an interesting perspective on the "Great Divergence" viewpoint. He cites Sugihara Kaoru's criticism of Wallerstein, acknowledging that the gap between East Asia and Europe was a significant but temporary separation, rather than the so-called

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3 Blakeslee was a professor of history and international relations at Clark University, and led the Far Eastern Unit at the State Department in 1942.

"Great Divergence." The reason is that the fusion of local and Western technology and experience was itself a part of the global division of labor. Regarding modern military history, Tonio Andrade (2017, 195) recognizes "The Great Military Divergence" between China and the West, while also acknowledging that local training facilitated the Chinese mastery of modern weapons, "although the world was a complicated place and each context demanded local solutions."

The impact of Krupp artillery on China has captured the attention of scholars both at home and abroad for over half a century. Stoecker (1958), utilizing a substantial amount of German diplomatic archives, reveals the role played by diplomats such as Max August Scipio von Brandt (1835–1915) in securing Krupp's monopolistic position in heavy weaponry in China. Over the past two decades, Yu Wentang (1998) has placed Krupp's arms sales to China within the context of Sino-German trade, exploring the commercial factors on which both parties relied. Kaske (2002) has proven adept at analyzing key figures and their communication networks, demonstrating the complex relationships among various players such as Krupp, German military instructors, and late Qing officials abroad, based on a wealth of first-hand German language sources (Baur 2005). Nicolas Schillinger's (2016; 2020) research, employing a unique perspective and rare historical sources, meticulously examines the methods and impact of German military instructors training Chinese soldiers during the late Qing and early Republic of China, leaving a profound impression. Jie Li (2021) and the author (Sun 2014) have both sought to complement their analyses by drawing upon both Chinese and German literature. The former focuses on the relationship between Li Hongzhang and Krupp, while the latter seeks to understand the process by which China absorbed Krupp's technology.

In 2011, Wolfgang König, while leading a special research project on "Making Technology Appropriate" (DFG project) jointly undertaken by the Technische Universität Berlin and the Institute for the History of Natural Sciences, posited that the study of military technology transfer between China and Germany and appropriate technology should give priority to the analysis of technological changes that arose from the aforementioned channels of interaction. These changes primarily involved alterations in German weapon technology to meet China's military and industrial needs, changes in China's local social environment to accommodate new technology, education or training of local personnel in contact with new technology, and modifications that occurred locally in the adoption and maintenance of foreign new technology. These changes not only highlight the importance of the localization process but also hint at the possibility of the emergence of appropriate technologies such as the "Krupp style."

2 Arms trade between the Vice King and the Cannon King

From the 1870s, Krupp had established a favorable relationship with the Chinese government, resulting in a prolonged period of extensive arms trading. Following the Franco-Prussian War (1870–1871), "German fever" in China fueled the reputation of German weaponry, leading the Chinese to readily embrace German artillery. Krupp quickly eclipsed Britain's Armstrong in terms of influence in the Chinese arms market, and the Germans capitalized upon this opportunity to develop an export conduit for their armaments to China.

China's fervent demand for German weapons was aimed at emulating Germany in the hopes of developing an army and navy that could rival those of Britain and France. In 1876, the Chinese ambassador to Germany, Xu Jingcheng 许景澄 (1845–1900), extolled "the German army as the best among the Western armies" (Xu [1918] 2015, 44).[4] In the view of Beiyang Minister Li Hongzhang, Germany's naval equipment was as exceptional as its army's, and "the German army is the most proficient in firearms and tactics, while the navy's ironclad ships have made rapid advancements" (Li 2008g, 366–367).[5] Other than Xu and Li, the German army and its weaponry also won the endorsement of influential figures such as Viceroy of Shaan-Gan Zuo Zongtang 左宗棠 (1812–1885), Viceroy of Huguang Zhang Zhidong 张之洞 (1837–1909), and Viceroy of Liangjiang Li Zongxi 李宗羲 (1818–1884), who commanded the late Qing elite troops. Xu Jingcheng proposed that the navy be equipped with Krupp's steel guns, while Li Hongzhang planned to exclusively utilize Krupp artillery in the military. However, in 1874, Li had to spend one million silver coins to purchase a mere fifty pieces, the exorbitant price of which caused him great distress (Li 2008j, 161). Zuo Zongtang and Zhang Zhidong sought to achieve self-sufficiency in shells and ammunition. While these officials had the authority to directly purchase military supplies, their urgent need made "both good quality and high expense" the characteristics of Krupp artillery in their eyes.

During his visit to Krupp in 1896, Li Hongzhang was honored with the title of "Vice King," as documented in Figure 1. Prior to this, A. Krupp had addressed Li as "von Ly" in accordance with German custom.[6] During Li's tenure, he was undoubtedly the most sought-after Chinese official by the Krupp family during the late Qing dynasty.[7] In fact, establishing direct channels of communication between Krupp and Li Hongzhang himself was a mutual desire, as evidenced in Figures 2.1–2.2. In furtherance of this aim,

4 "泰西陆军之精，推德意志国为最。"
5 "德国陆军枪炮、操法最为擅长，近来水师铁甲兵船亦日新月异。"
6 Familien-Archiv Hügel, FAH2B 363a, 73, 255, Historisches Archiv Krupp (henceforth referred to as HAK).
7 The Krupp Corporation once presented Li Hongzhang with a portrait of Li himself, a large copper bell, and a valuable model of a railway locomotive. The Krupp Historical Archive still retains Li's letters, photographs, and other records. In contrast, no other Chinese officials left any evidence of such close relationships with the company. Unfortunately, only a few remnants of an extensive collection of correspondence between Li and foreign individuals have been preserved in his own archives.

Li dispatched to Germany some of the foremost intellectuals from the Group Advocating Self-Strengthening, such as Li Fengbao 李凤苞 (1834–1887) and Xu Jianyin 徐建寅 (1845–1901), for the purpose of fostering communication. At that time, R. Hart (1835–1911), the British Inspector-General of the Imperial Maritime Customs Service, derided Li Hongzhang as an unswerving follower of Germany and Krupp since 1870 (Chen 1990, 332).


FRIED. KRUPP.

Schiessversuche
auf dem
Schiessplatze bei Meppen
in Anwesenheit
Seiner Excellenz des Vice-Königs
Li Hung-Chang
am
Mittwoch, 1. Juli 1896

Vorläufiges Programm.

Figure 1: The itinerary of Li Hongzhang's visit to Krupp.[8]

Alfred Krupp (1812–1887), known as the "Cannon King" (der Kanonen König), valued the favor of China as an Eastern power. However, his company had limited knowledge of China's specific needs, resulting in the payment of commissions to German diplomats and businesspeople in China for information. The German envoy to China, Max August Scipio von Brandt, continuously worked to persuade the Chinese to purchase Krupp artillery. He understood better than A. Krupp himself the purchasing desires and financial capabilities of Chinese officials such as Li Hongzhang. At the same time, he quarreled constantly with Krupp's competitors in Britain and France, and due to conflicting interests was even on bad terms with F. Peil and H. Mandl & Co., agents of Krupp's products. In Essen, Krupp and his son had entertained Chinese guests on several

8 Familien-Archiv Hügel, FAH3H 37:1, HAK.

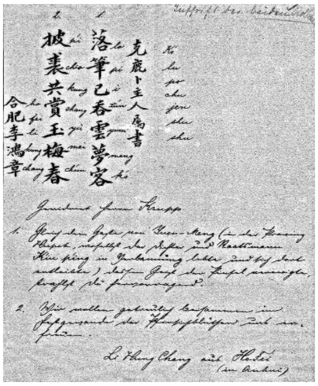

Figure 2.1: Li Hongzhang's poetic inscription for the Krupp family.[9]


地精明性情平正具見
貴商經營大事用人得當昨接
李大臣來函云
貴商身體偶有違和本大臣深
為記念尚望時加保養以冀康
強是為至盼專覆順候
近好不一

Figure 2.2: Li Hongzhang's letter to Alfred Krupp.[10]

occasions at Villa Hügel and the factory. However, visiting diplomats mainly expressed a willingness to purchase as much as possible, rarely making specific demands regarding technical details.

There was at least one exception—Krupp had, in fact, responded to the Chinese specialists' technological demand by designing and producing a limited quantity of heavy naval artillery pieces for Li Hongzhang's Beiyang Fleet. During the 1870s and 1880s, Li's proposal for fortifying the coast was sanctioned. This involved the production of several hundred naval guns and coastal artillery pieces for dozens of military ships and costal forts, including large-caliber guns (Sun 2014). Krupp took pains to fulfill China's request for "numerous and large" artillery. When the Germans proffered their SMS *Sachsen*[11] to the Chinese, Li Fengbao and Xu Jianyin were not satisfied with the vessel's configuration of six 26-centimeter main guns and their protective gear. The duo opted to commission Krupp to tailor 305 mm large-caliber dual main guns (Figure 3), along with protective amor clad modeled after the British *Inflexible* battleship, for China's largest vessels *Zhenyuan* 镇远 and *Dingyuan* 定远 (Xu [1908] 1980, 68, 85–86). The cost of purchasing artillery pieces for one of the vessels alone amounted to 593,845 silver taels (Li and Jia 2010). Despite boasting a larger 305 mm caliber compared to the German navy's heftiest 280 mm dual guns at the time, Krupp's technology was, however, inferior to the latter's (Figure 4).

9 Familien-Archiv Hügel, FAH3C 44:5, HAK.
10 Familien-Archiv Hügel, FAH2B 303:7, HAK.
11 SMS *Sachsen* was the lead ship of her class of the German Kaiserliche Marine. It was commissioned in 1878 and broken up in 1919.

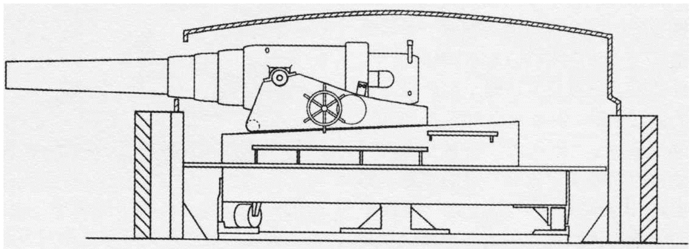

Figure 3: The Krupp 305 mm naval gun on the *Dingyuan* and *Zhenyuan* battleships (1884) (drawn by Liu Xuanhe 刘烜赫) (Chen 2006, 15).

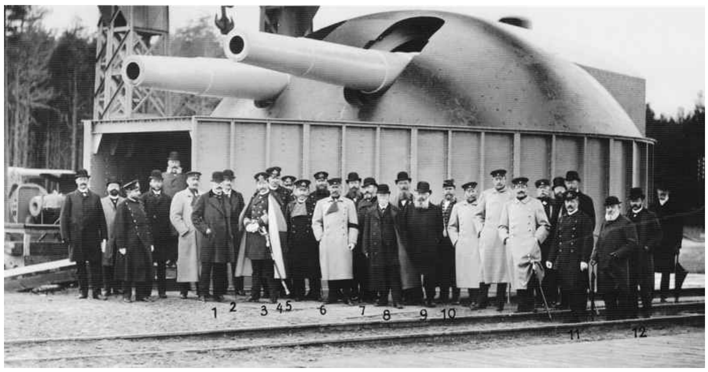

Figure 4: The Krupp 280 mm dual naval gun produced for the German navy (1892) (Tenfelde 2005, 18).

In 1880, the Krupp company dispatched Karl Menshausen to China to meet Li Hongzhang, and succeeded in persuading the latter to replace the originally ordered lead shells with a new type of copper shells. Krupp also marketed a new weapon known as the Pivot-Kannonen-boot.[12] This new type of waterborne artillery platform developed by Krupp, with a small ship and a large gun, was well-received by Li Hongzhang and was almost tailor-made for his Beiyang Fleet. Perhaps due to a lack of funds, Li asked Menshausen to send a letter declining the possibility of upgrading the shells and did not explicitly agree to purchase the Pivot ship. However, he subsequently consented to purchase the Fahrpanzer, an expensive wheeled mobile armored artillery, and by the end of 1889, the Beiyang Fleet was equipped with a small number of them.[13] Notably, the Qing army were likely the earliest in the world to utilize this new type of artillery among artillery troops (Figures 5–6), predating their use by Germany in 1890 and the subsequent adoption by countries such as Bulgaria, Romania, Greece, and Italy (Anonymous 1894, 1994–1998; Anonymous 1890, 173–180).

12 Familien-Archiv Hügel, WA IV 1461, 1, 3, HAK.
13 R901/8465, 29, Bundesarchiv Berlin-Lichterfeld.

Figure 5: Fahrpanzer and the Chinese artillery team.

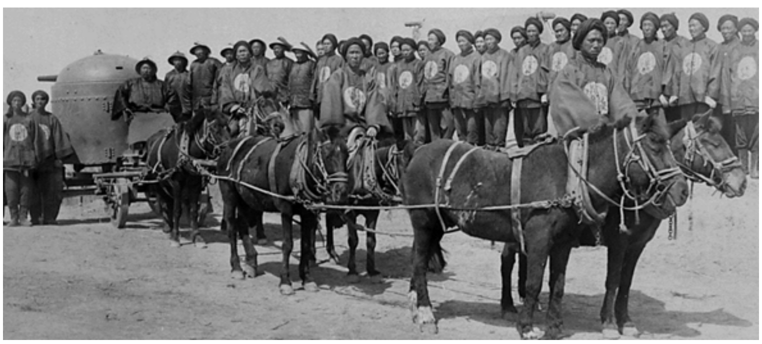

Figure 6: Chinese soldiers driving a Fahrpanzer using a traditional animal-drawn transport (Anonymous 1890, 173–180).

The relationship between Li Hongzhang and Krupp serves as a microcosm of the substantial importation of Western weaponry during the late Qing dynasty. In just one order in 1887, Li Hongzhang paid H. Mandl & Co. approximately 1.75 million marks (Stoecker 1958, 214). Within a span of fifty years, Krupp artillery purchased by the Chinese navy and army proliferated across nearly a hundred ships in the Beiyang, Nanyang, Guangdong, and Fujian Fleets, as well as dozens of coastal forts from Lüshun, Weihai, to Guangzhou, and became popular in army camps in Lianghu, Guangdong, and northwestern China. In total, between 1871 and 1911, Krupp recorded the sale of

2510 various types of artillery to China, as displayed in Table 1.[14] If we were to include the second-hand goods purchased through other channels by foreign firms excluded from the factory statistics, the total number of artillery purchased by China from Krupp during their forty years of trade and exchange would have been around 3000, accompanied by imported shells, ammunition, and supporting equipment, with an estimated cost of around 50 million silver taels for the Chinese side.[15]

Table 1: Statistics of the quantity of various types of artillery sold by Krupp to China from 1871 to 1911 (Krupp factory statistics)

1870–1879	Number	1880–1889	Number	1890–1899	Number	1900–1912	Number
1870	/	1880	29	1890	48	1900	/
1871	24	1881	27	1891	12	1901	/
1872	50	1882	83	1892	62	1902	29
1873	117	1883	22	1893	34	1903	16
1874	55	1884	286	1894	289	1904	72
1875	136	1885	125	1895	40	1905	18
1876	10	1886	31	1896	123	1906	43
1877	45	1887	56	1897	3	1907	49
1878	1	1888	124	1898	20	1908	76
1879	/	1889	157	1899	6	1909	114
Note: The statistics do not account for second-hand Krupp artillery purchased by China from other countries during different periods.						1910	1
						1911	7

Source: Data from Familien-Archiv Hügel, WT 1/4 S3 49, 19, HAK.

The Krupp company catered to China's thirst for both quantity and tonnage of artillery, and China rapidly established a staggering modern artillery force with these

14 The table has four blank sales cells, each the result of unique circumstances. The absence of any data before 1870 is due to China's prior lack of official ordering from Krupp. In 1879, several interest groups in Germany called on Bismarck to adjust trade policies, and the Central Association of German Industrialists (Zentralverband deutscher Industrieller) and other organizations proposed the implementation of protective tariffs. As a member of the Association of German Iron and Steel Industrialists (Verein Deutscher Eisen- und Stahlindustrieller) under this organization, Krupp consequently scaled back its exports. During the period of 1900 and 1901, Germany engaged in the military intervention of the Eight-Nation Alliance against China, and afterwards joined the arms embargo on China. Krupp, therefore, refrained from directly selling weapons to China. However, this did not rule out the possibility of foreign firms bypassing the ban and exporting Krupp's weaponry to China through other countries.

15 At the time, such an expense was nothing short of staggering, amounting to approximately 7.5 million pounds. To put things in perspective, the Final Protocol for the Settlement of the Disturbances of 1900 required China to pay 450 million taels of silver, equivalent to 67.5 million pounds.

new breech-loading steel guns. In less than half a century, the Chinese army purchased various Krupp artillery and a large amount of ammunition, ranging from 37 mm field artillery to the 305 mm main guns of the *Dingyuan* and *Zhenyuan* ironclads. Over ten thousand artillery troops were stationed on ships, forts, and barracks throughout China. Both China and Germany had the power of choice in arms trading, and the heated trade in Krupp's weaponry not only reflected Germany's emphasis on promoting arms with high added value, but also stemmed from Li Hongzhang, Li Fengbao, and Xu Jingcheng's preference for state-of-the-art, high-end weapons.

Both parties appeared to place great importance on new technology, but corresponding technological risks had long been looming within the arms trade. Although Krupp's sales strategy, which involved offering multiple models and prioritizing high-end artillery, met the needs of the late Qing's change to modernized weaponry, employing multiple models and expensive equipment was not the optimal option for the military. The Germans may have never informed the Chinese of this issue, and Li Hongzhang and contemporaries failed to pay it adequate attention. Additionally, the exorbitant price of Krupp products compelled Li Hongzhang and his peers to resort to the tactic of "using [the merits of] the foreign against them" (*yi yi zhi yi* 以夷制夷), consequently diverting their focus and military expenditures towards Armstrong in the UK and Schneider in France. These decisions led to a haphazard mix of weapon types, combat training, and logistics support within the Chinese army, ultimately exposing fatal flaws during the subsequent Sino-Japanese War and Boxer Rebellion (1899–1901).

In 1906, five years after the passing of Li Hongzhang, another important official, Dai Hongci 戴鸿慈 (1853–1910) ([1906] 2017, 162), paid a visit to Krupp's artillery factory and observed that the Japanese were procuring four hundred "most convenient to use" 75 mm recoil-operated guns. This procurement practice contrasted markedly with China's prior strategy for importing weapons. It is conceivable that even though the Chinese swiftly built up a seemingly impressive army utilizing the Krupp artillery they acquired, the German-style firepower that triumphed in the Franco-Prussian War did not emerge in China.

3 Imitation and uniformity of "Krupp-style" artillery

The procurement of Krupp artillery was not the sole recourse for China. Indeed, the production of "Krupp-style" weaponry was also a viable option, especially for Zuo Zongtang and Zhang Zhidong who prioritized self-manufacture. In the late Qing dynasty, several new-style arsenals in China endeavored to replicate Krupp artillery and ammunition, the most notable case being the large quantities of "Krupp-style" 75 mm breech-loading steel guns produced by the Jiangnan Arsenal. The emulation process was primarily predicated on surveying and copying, with the foundation of the Chinese ordnance manufacturing industry's capabilities stemming mainly from previously absorbed British technology. Yet, despite substantial investment in artillery production arsenals, manufacturing capacity could never keep up with demand. It was not until the 1930s, under the Nationalist Government in Nanjing, that the standardization of production finally began to get on the right track.

Chinese understanding of Krupp artillery manufacturing technology underwent an arduous journey. Initially, the Chinese were confident in their ability to imitate Krupp technology, but the ensuing difficulties proved to be far more complex than anticipated. The views of Zhang Zhidong and Li Zongxi were representative of the time, both advocating for "purchasing [the weaponry] while learning the manufacturing" (Li [1885] 1969, 406).[16] Zhang held the belief that the technology for manufacturing artillery was transferrable, and that with the acquisition of proper machinery, Chinese factories could successfully replicate the artillery (Zhang 1998, 307–309). In the early 1870s, Li Hongzhang instructed Samuel Halliday McCartney (1833–1906), a former British military doctor, to imitate a small Krupp-style artillery piece at the Jinling Arsenal. Although McCartney was more knowledgeable than most Chinese, the wrought iron "Krupp-style" artillery he produced fell far behind the performance of pure steel Krupp artillery (Qingdao Museum, The First Historical Archives of China, and Qingdao Institute of Social Sciences 1987, 30–31). Li Hongzhang may have been influenced by McCartney and deemed the imitation of the British wrought iron artillery more reliable. However, after unsuccessful attempts at imitating wrought iron "Krupp-style" artillery in northwestern China, Zuo Zongtang became a staunch advocate for the importance of using steel. Unfortunately, at the time, China lacked the ability to produce gun steel. Zhang Zhidong conjectured that "only two people at Krupp know how to manufacture cannon steel" (Zhang 1998, 307–309).[17] Wu Dacheng 吴大澄 (1835–1902), an ardent supporter of Krupp artillery, even asserted that it was impossible to imitate Krupp artillery, comparing it to the challenge of replicating silk from Huzhou or satin from Jinling and Hangzhou in China (Wang [1978] 2009, 43).

During the 1870s, after simple trials Chinese arsenals gave up their early efforts to imitate Krupp's artillery. Instead, they gradually began to emulate the production of "Krupp-style" gunpowder and shells. By 1874, the powder factory of the Jiangnan Arsenal had acquired the capability to mechanically produce the black powder. This substance, consisting of 75% potassium nitrate, 15% charcoal, and 10% sulfur, was not unfamiliar to the Chinese. Traditional handiwork, however, was inadequate for large-scale production, and the challenge lay in mechanized production, which included

16 "一边购买，一边学习制造。"

17 "在克虏伯厂，只有两个人懂得制造大炮钢材的方法。"

crushing, granulating, sieving, polishing with graphite powder, and drying. When China imported a significant amount of Krupp artillery, they discovered the need to utilize brown gunpowder or more advanced smokeless powder. The former was a variation of black powder, while the latter was a new variety made from nitrocellulose and nitroglycerin. Under the instruction of Li Hongzhang and others, the Jiangnan and Tianjin Arsenals concurrently laid out plans for the production of these two types of gunpowder from the 1880s onwards.

Li Hongzhang and his peers were of unanimous conviction that purchasing machines and hiring foreign artisans were of paramount importance. Xu Jingcheng, the envoy to Germany, was entrusted with responsibility for these two critical matters. While China acquired machinery and foreign artisans from Germany, none came from the Krupp factory, probably due to Li and Xu's considerations of cost. Nonetheless, a set of machinery for producing brown gunpowder cost more than ten thousand silver taels, and the monthly remuneration of a foreign artisan was 300 taels (equivalent to approximately 200 pounds). Nie Qigui 聂缉椝 (1855–1911), Director of the Jiangnan Arsenal, suggested that although brown gunpowder was "urgently needed" (急需), foreign artisans should impart their skills to the Chinese while manufacturing, thereby "achieving two objectives with one action" (一举两得) (Editorial Committee 1993, 392–393).

The raw material for brown gunpowder was willow strips, which had to undergo sixteen processes, such as roasting, pressure processing, and drying. Indeed, the drying process, rather than the materials or equipment, presented the greatest challenge to those seeking to replicate the gunpowder. In a bid to compare their imitated products with those of Krupp's, Li Hongzhang ordered the Beiyang Fleet to perform chemical analysis and live ammunition trials. The result was that Krupp-style gunpowder had slightly higher moisture content (Li 2008c, 344). As such, the Jiangnan and Tianjin Arsenals had to explore improvements to their production methods. With this problem resolved and the techniques mastered by local artisans, the Qing government bestowed medals upon several foreign artisans (Li 2008l, 45–46).

It was not until 1893 that the "Krupp-style" smokeless gunpowder was put into production. The strategy employed to imitate this powder was akin to that used for brown gunpowder, involving the procurement of machines and the enlistment of foreign artisans. The machinery for smokeless gunpowder was produced by Gruson Werk of Magdeburg-Buckau, another German arms factory. However, it seems that the Germans had no intention of imparting their knowledge to their Chinese partners this time. Consequently, foreign artisans were primarily responsible for equipment rather than technology. In contrast to the technical similarities between black gunpowder and brown gunpowder, the production of smokeless gunpowder entailed entirely different raw materials and processes. For the Jiangnan Arsenal, the task of replicating such a novel gunpowder posed a considerably greater challenge than that of brown gunpowder. At that time, China lacked the capacity to produce basic chemical raw materials, such as sulfuric acid and nitric acid, and was unfamiliar with the details of specific chemical reactions, including dosages, processes, time, and temperature. As a result, Zhang Zhidong had to invite Xu Jianyin to explore the manufacturing process of smokeless gunpowder at the Hanyang Arsenal. Even by 1895, during the Sino-Japanese War, China's homemade smokeless gunpowder remained substandard. After the conclusion of the war, the Jiangnan Arsenal enlisted the services of Japanese expert Ishido Toyota to oversee production, leading to a complete overhaul of the process in line with the Japanese style (Jiangnan Arsenal 1910, *juan* 4).

The replication of "Krupp-style" separated ammunition began in the 1870s, but it was not until after 1890 that the ability to mass-produce fixed ammunition was established. Most early Krupp artillery imported utilized separated ammunition without a projectile casing. The imitation was conducted through reverse engineering, involving the disassembly of the projectile, measurement, and refinement during trial production. With the purchase of a large quantity of machine tools and casting equipment from the United States at its inception, the Jiangnan Arsenal was capable of resolving the technical obstacles of projectile production, including cutting technology and shell casting. In 1874 alone, the Jiangnan Arsenal's annual output of "Krupp-style" projectiles reached 8306 (Jiangnan Arsenal 1910, *juan* 3 and 5). As a result, other arsenals across the nation, including the Jinling, Sichuan, Jilin, Hubei, Shanxi, and Fujian Arsenals, followed the Jiangnan Arsenal's techniques and replicated the artillery.

The reason why the mastery of fixed ammunition was delayed by twenty years compared to separated ammunition can largely be attributed to the two aspects of raw materials and technology. Approximately forty procedures were involved in the production of such projectiles. Notably, a substantial amount of copper needed to be imported from Britain, and the processing and assembly of the copper casing, fuses, and pyrotechnics had to be executed with exceptional precision. Historical records reveal that the Jiangnan Arsenal commenced imitating the process as late as 1906, with a particular focus on the 75 mm Krupp and "Krupp-style" artillery, ultimately achieving an annual output of up to 14,500 (Jiangnan Arsenal 1910, *juan* 2).

In 1890, Li Hongzhang was once again presented with a proposal to replicate the "Krupp-style" artillery. Prior to this, as a result of the Jiangnan Arsenal's successful replications of British Armstrong muzzle-loading and breech-loading guns, the arsenal's personnel became familiar with the raw materials, technology, and British machinery used at the Arsenal. General Director Liu Qixiang 刘麒祥 (1846–1897) proposed a "reliable" method to Li Hongzhang—reverse engineering: first, purchase a

Krupp gun, disassemble and measure it piece by piece, and then compare it with past imitation experience, thus ultimately attaining production. Li fully concurred with the proposal (Editorial Committee 1993, 512–513).

To achieve self-sufficiency in producing "Krupp-style" artillery, the Jiangnan Arsenal established a steel mill and gun factory in 1890. Undoubtedly, these fundamental capabilities were also necessary for the Jiangnan Arsenal to produce naval ships and other equipment. It expended a substantial sum of 17,865 pounds to purchase from Britain a large quantity of equipment, such as steel furnaces, 2000 horsepower 50-ton steam hammers, 1000 horsepower 2000-ton hydraulic presses, rolling mills, and cranes driven by 2000 horsepower double cylindrical steam engines. The foreign craftsmen in the gun factory received a monthly remuneration of 650 taels (about 90 pounds) each, whereas the total monthly salary of the 166 local craftsmen was 636 taels. As for the steel mill, the foreign artisans were paid 473 taels per month, while their 149 local counterparts received a total monthly salary of only 420 taels (Jiangnan Arsenal 1910, *juan* 2). In 1902, the Jiangnan Arsenal's gun factory undertook the trial production of five models of emulated Krupp-style breech-loading guns (Table 2, Figure 7), which were gradually supplied to the army, but this did not give rise to the concept of weapon standardization.

Table 2: The trial production of Krupp-style guns by the Jiangnan Arsenal

Gun	Caliber (mm)	Gun length (m)	Gun weight (lb)	Projectile weight (lb)	Propellant (kg)		Range (m)
					Brown powder	Black powder	
150 Gun	150	4.6	9922.5	80	15.6	25	7500
120 Gun	120	5	5138	40	4.5	12	7200
76 Gun	76	1.3	1267	12	0.41	8.3	4300
57 Gun	57	2.8	1280	6	0.4	1.5	8000
47 Gun	47	0.92	248	3	0.15	0.35	3000

Source: Data from Sun (2014).

The production strategy of replicating various models fell into the same trap as the arms trade. It was not until the Sino-Japanese War that the late Qing military leadership realized the importance of standardization. In fact, as early as 1878, Li Hongzhang had recommended the "uniformity" (*huayi* 画一) of weapons to the court. However, Li (2008h, 126–129) merely implied that all artillery should utilize breech-loading steel guns, without specifying technical standards such as caliber and length. Xu Jingcheng ([1918] 2015, 20–24) misunderstood this to mean that uniformity could be achieved merely by employing Krupp guns in the navy. It was not until 1898 that the Qing government recognized the "formulation" (*geshi* 格式) of weapons as a vital issue (Editorial Committee 1993, 559), requiring that firearms manufactured by various

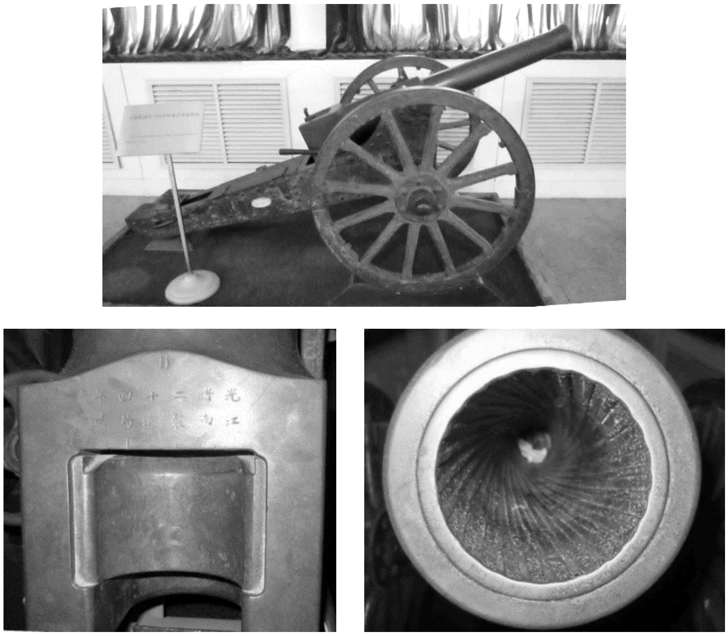

Figure 7: The Jiangnan Arsenal's replicated Krupp-style 57 mm gun, gun port, and bore (1898) (The Military Museum of the Chinese People's Revolution, photos by Sun Lie).

provincial arsenals be of the same type, with uniform ammunition types, weight, and techniques (Liu 2018, 583–587). Zhang Zhidong was particularly active in addressing this concern, asserting that the Chinese army's haphazard variety of firearms was the most serious problem during the preceding decades. Influenced by Japan, he recommended that the main battle gun should have a caliber of 75 mm (Editorial Committee 1993, 298). After the Jiangnan Arsenal consulted with the Hubei and Tianjin Arsenals, it was unanimously agreed that the Krupp 75 mm mountain gun was the most appropriate model to emulate.

In 1905, the Jiangnan Arsenal conducted trial production of the "Krupp-style" 75 mm mountain gun, which was set as China's first standardized artillery in 1907 (Figure 8). Three years later, the Ministry of War instructed the Jiangnan and Hubei Arsenals to exclusively manufacture this particular ordnance and to stop producing other types. In terms of quantity, from its official production in 1907 to its cessation in 1928, the Jiangnan Arsenal produced a total of 494 guns. Inclusive of the imitation of smoothbore muzzle-loading guns back in 1867, the arsenal produced a total of 1075 guns of diverse kinds, with the 75 mm Krupp recoil-operated mountain guns produced in Shanghai comprising nearly half. This demonstrates the significance of this gun for the Jiangnan Arsenal. Despite a planned annual production of 50 guns per year, the Arsenal's actual output was less than half of this (Editorial Committee

1998, 72–73, 139).

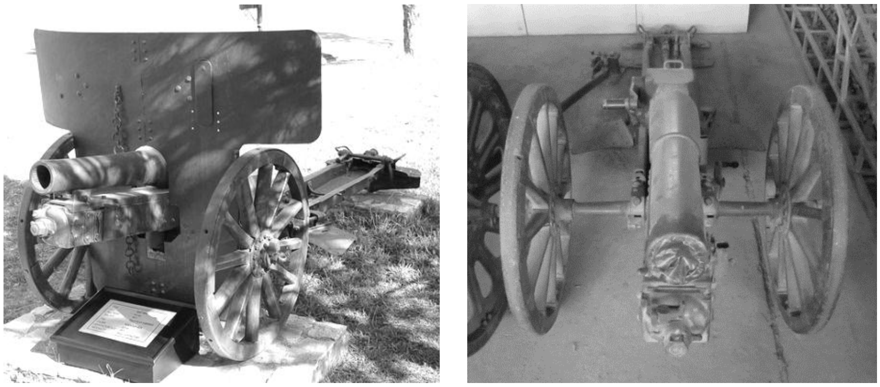

Figure 8: The Krupp 75 mm mountain gun and the Jiangnan Arsenal's 75 mm "Krupp-style" mountain gun (photos by Sun Lie).

The "Krupp-style" mountain gun was still produced through disassembly, measurement, and subsequent replication. Krupp's artillery could be dismantled into 176 components, including the most important barrel, Krupp-style breech-block, and wheeled mount (Table 3). Unlike earlier emulations, the "Krupp-style" gun featured a self-produced steel barrel, sourced solely from ingots from the factory's open hearth. In addition, the factory had established a quality inspection system. According to *On Replicating the Krupp Guns* (*Fangzao Kelubu pao shuo* 仿造克鹿卜炮说) (Figure 9), the self-produced steel's carbon content, ultimate strength, and yield limit were on par with those of Krupp's products (Wei 1905; Jiangnan Arsenal 1910, 63). However, this assertion was somewhat exaggerated. A comparison of the main parameters of the two revealed that the "Krupp-style" gun was heavier, had a slower rate of fire, and a shorter range (Table 4). This indicates that the increase in barrel wall thickness may have been required due to the inadequate strength of local materials, and that the quality of "Krupp-style" ammunition was also inferior to that of Krupp's products.

The emulation of Krupp products was motivated not only by the objective of drawing closer to the Krupp standard, but also by the introduction of certain differences that would set it apart. This localization characteristic was manifested in various intriguing details, including differences in the breech-block, shield, and wheel tread of the two models, elements difficult to explain through a process of measurement-based imitation alone. The early "Krupp-style" guns employed the Armstrong screw blocks, indicating evident difficulties in making Krupp's wedge-shaped breech-blocks encountered by the Jiangnan Arsenal at that time. The omission of shields in the local "Krupp-style" guns was potentially a measure to save costs and weight. Furthermore, the special design of the gun's wheelbase, with a width of 762 mm, which was aligned with that of the early Shanghai railways, was likely intended to facilitate transportation or part replacement of the gun. If indeed that was the case, it would represent a bold attempt achieved by the "Krupp-style" guns.


仿造克鹿卜礮說
礮身
查本局大小礮料係用西門司馬丁鋼爐煅鍊而成拉力達於
四十四噸與克鹿卜罐鋼礮料同一堅固大礮壓以水力小礮
擊以汽錘錘法將鋼塊燒至白亮之色鉗置五十噸力汽錘之
下轉動六十馬力汽爐門俾進汽於汽缸之內以一人開閉汽
門則汽錘自隨意升降鋼塊展轉受擊擊至合度而止即成小
礮礮身胚料加以車鑽工夫則該礮基礎已立從前本局各種
小礮皆用一段整鋼造成今管退礮礮身內一鋼管外一鋼套
鋼套籠罩鋼管合而爲一件法將鋼套燒熱至五百度趁其漲
大立時套上既冷之後箝束緊密與整段者無異放時受藥漲
江南製造局記 附 克鹿卜礮說 一

Figure 9: *On Replicating the Krupp Guns* printed in 1905 (Wei 1905, 1).

Table 3: Main components of the Shanghai emulated 75 mm Krupp-style mountain guns

Category	Components	Quantity
Gun barrel	Barrel, steel tube and steel sleeve, screws, gunlock wrench of breech	4
Breech-block	Breech-block, frame, flat spring, hammer and fire pin, hole, ejector, etc.	16
Platform	Steel slide, steel frame, steel support for the central pillar, cross-shaped steel frame, recoil cylinder, compression spring and copper seat, leather cup, hinged steel frame, sight scale, sight, etc.	69
Elevation handle	Elevating screw pin and chain, elevating screw nuts, copper bevel gear, copper handwheel, etc.	14
Traversing handle	Traversing steel frame, steel gear, copper handwheel, etc.	12
Gunmount	Steel sleeve for protecting the shaft, seat hinge, angled iron brace, steel hinge, pry, steel joint	14
Wheel	Wooden wheel, iron hoop, wheel shaft, inner and outer copper clamps	47
	Total	176

Source: Data from Wei (1905, 7–27).

Table 4: Comparison of selected parameters between Krupp 75 mm mountain gun and the Krupp gun

Denomination	7.5 cm Gebirgs-Kanone M.05	The Shanghai emulated 75 mm Krupp-style mountain guns
Caliber	75 mm	75 mm
Barrel length	1050 mm	1050 mm
Length-diameter ratio	14	14
Weight of the barrel	105 kg	225 pounds
Breech-block	Krupp wedge breech mechanism	Krupp wedge breech mechanism, previously Armstrong screw block (changed in 1908)
Suppress and advance	Hydraulic type spring	Hydraulic type spring
Shield	1 steel shield, thickness 3 mm, weight 24.6 kg	0
Elevation	+25°/−10° (could be raised to 32°42′ and shoot up to 5000 m)	+15°/−8° (could be raised to 23°, with additional steel plate)
Traversing angle	4°	4°
Universal shell	5.1 kg (including 106 g of picric acid)	5.3 kg (without smokeless gunpowder)
Muzzle velocity	330 m/s	280 m/s
Max. range	5000 m	4300 m
Max. angle of descent	5000 m at 32° 42′	4000 m at 20°
Barrel grooves	28 (depth 0.75 mm, width 5.92 mm)	28 (depth 0.75 mm, width 5.92 mm)
Height of wheels	800 mm	800 mm
Track	740 mm	762 mm
Transport	4 horses	4 mules
Ammunition	128 shells (16 boxes, with 8 rounds each, each ammunition pack animal carrying 2 boxes—each ammunition box with 8 rounds weights 52.3 kg)	Unknown

Sources: Data from Bethell (1910, 179–183) and Wei (1905, 10–27).

In the early twentieth century, despite the ability of Chinese arsenals to emulate the "Krupp-style" artillery, the lack of technical expertise and effective management impeded any major strides forward. As a representative of the Associated Chambers of Commerce of Great Britain, Lord Charles Beresford (1846–1919), a retired British naval admiral, undertook an investigative expedition to Chinese arsenals in 1898. As an expert, he witnessed a scene of modern machinery coexisting with obsolete manufacturing procedures. He held that:

> The machinery, which is modern, and of first-class make, is entirely devoted to making obsolete and useless war material. A large number of small guns are being made throwing about a 1 lb. shell. There are, too, some 5 pr. guns being made on the Krupp pattern, but without limbers, the guns' crews being supposed to carry the ammunition.
>
> . . . This arsenal is under the provincial government of the Viceroy of Hupeh and Hunan. It has a first-rate modern plant, all by German makers. I noticed a large number of modern milling machines. . . . The work turned out in this arsenal was another

> instance of the terrible waste of money in manufacturing war material of no possible value. I saw heavy and expensive machinery lying about all over the yard, intended for the manufacture of I2″ 50-ton guns of Krupp pattern. None of this machinery had been set up. I also saw a large quantity of machinery for a powder mill, but this had not been set up either. (Beresford 1899, 298–300)

There is no evidence suggesting that Chinese factories received direct support and assistance from Krupp during the replication process of the "Krupp-style" artillery. Despite importing Krupp products, Li Hongzhang and others did not purchase the production and maintenance technology for Krupp's guns, ammunition, or accessories. The Germans were not indifferent to the Chinese imitation activities. Clues in the Krupp archives reveal the company's principle towards China: a fervor for arms trade but apathy towards technological collaboration. For this German "arsenal," China was merely a massive arms market, and Chinese imitation activities posed no substantial threat to Krupp's sales at that time. During the replication process, Chinese arsenals strove to obtain machinery, raw materials, or production technology from various countries such as Britain, the United States, and Germany. This approach not only complied with the Qing government's political policy of maintaining a balance among major Western countries, but also contributed to the formation of an independent technological system, ultimately leading to self-production.

After World War I, Chinese arsenals shifted their focus to Japanese weapons, leading to a relative decline in the production of "Krupp-style" weapons. Nevertheless, the development of the 75 mm standardized artillery had taken root in China. In 1932, the Chinese Ordnance Department formulated the first comprehensive list of standard weapons, with field artillery continuing with a 75 mm caliber to meet China's actual situation (Ordnance Department 1932, 1–86).[18] During the 1930s, Krupp agreed for the first time to undertake the design and construction of a central steel plant and a new arsenal at the invitation of the Chinese government, in addition to supplying an entire suite of equipment.[19] However, the onset of Japan's invasion of China in 1931 and the subsequent outbreak of the full-scale War of Resistance against Japanese Aggression in 1937 prevented the emergence of the new "Krupp-style" weapons.

4 Localization of knowledge in the use of artillery

As greater numbers of Krupp and "Krupp-style" artillery were delivered to Chinese ships and barracks, Chinese soldiers were swiftly updated in their use. Li Hongzhang and his contemporaries implemented a range of measures, including the employment

18 "The Gunner Department's Opinions on the Standardization of Guns" 张砤[炮]兵监炮制式意见书, file 0033-0017-00367, 14–18, Chongqing Archives.
19 WA 51/5458, HAK.

of German military personnel as instructors, sending Chinese soldiers to study in Germany, translating Krupp materials, constructing forts, and adopting diverse forms of battlefield deployment. In doing so, a substantial amount of modern military theory and operational practices were introduced into China in the appropriate form.

From the 1870s onwards, more than one hundred Germans served as military technology instructors in China. These instructors, largely retired military personnel, were recommended by German or Chinese diplomats and invited by Li Hongzhang and Zhang Zhidong. Among the most influential were Theodor Schnell (瑞乃尔, ?–1897), Constantin von Hanneken (哈纳根, 1855–1925), C. Lehmeyer (李迈协), D. Ilgner, Baron von Reitzenstein, and Georg Baur (1859–1935). Ilgner and Baron von Reitzenstein, both military-technical advisors (militarisch-technische Berater), were hired directly by Krupp, while Baur was also an experienced railway construction engineer.

Based on their actual actions while in China, these German experts were tasked with three primary missions. Their first objective was to instruct the Chinese on the use and maintenance of Krupp artillery, and to provide guidance on the implementation of related military engineering projects. Secondly, they were engaged as salespeople for Krupp armaments. Lastly, they were responsible for gathering intelligence for the company. In fact, these duties were closely interrelated, with the first two akin to after- and pre-sales services, while the third relied on the first two. The German envoy to China, Max August Scipio von Brandt, exercised a degree of control of these experts, and in the view of German diplomats, deploying military instructors to China was an effective way of limiting the influence of other countries on China's military, reducing the threat foreign competitors could pose to Krupp's product sales (Stoecker 1958, 197–277). During his visit to the embassy as a diplomat in 1903,[20] Gustav von Bohlen und Halbach (1870–1950) encountered a retired German officer who was instructing and promoting Krupp's military arms in China.[21] These experts enjoyed substantial earnings, with China offering an annual salary of 18,000 marks (Stoecker 1958, 164).

With around thirty years' service in the Chinese military, Schnell witnessed almost the entire Self-Strengthening Movement. Upon arriving in China, he enlisted in Li Hongzhang's Huai Army and the Beiyang Fleet, and was primarily tasked with instructing Chinese soldiers in the use of Krupp artillery. As the first German military instructor employed by Li, Schnell improved Chinese troops' understanding of the deployment of German weaponry. He also led a contingent of Chinese soldiers selected by Li to receive training in Germany. In 1890, through oral dictation, his student Duan

20 At that time, he had not yet married Bertha Krupp (1886–1957) and was not yet the head of the Krupp family.

21 Krupp und Cina: Dialog mit Dimension, 16, Fried. Krupp AG Hoesch-Krupp.

Qirui 段祺瑞[22] (1865–1936) translated[23] into Chinese an *Illustrated Treatise on the Krupp Quick-Firing Guns* (*Kelubo kuaipao tushuo* 克虏伯快炮图说) (Figure 10), and in the following year, another book *Illustrated Treatise on the Krupp Shells* (*Kelubo paodan tushuo* 克虏伯炮弹图说), both of which became textbooks for military academies. Schnell garnered the trust of both Li Hongzhang and navy admiral Ding Baozhen 丁宝桢, the latter recommending that the Qing court bestow a medal upon Schnell (Ding [1893] 2000, 391). Schnell later also worked part-time in foreign trading companies and actively promoted Krupp artillery.[24]

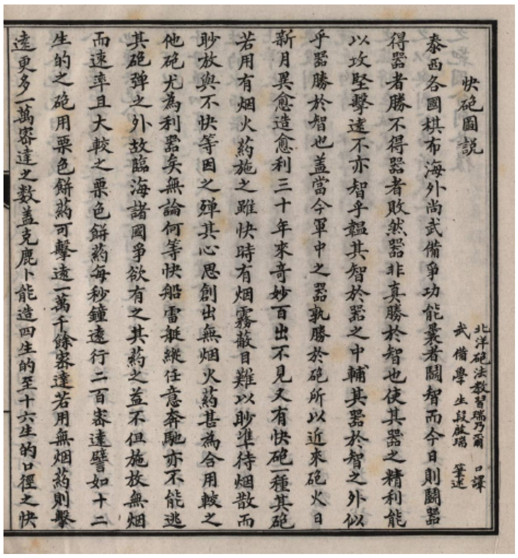
快砲圖說
北洋砲法教習瑞乃爾 口譯
武備學生段祺瑞 筆述
泰西各國棋布海外尚武備爭功能衆者鬭智而今日則鬭器得器者勝不得器者敗然器非真勝於智也使其器之精利能以攻堅擊遠不亦智乎韞其智於器之中輔其器於智之外似乎器勝於智也蓋當今軍中之器孰勝於砲所以近來砲火日新月異愈造愈利三十年來奇妙百出不見又有快砲一種其砲若用有烟火葯施之雖快時有烟霧蔽目難以眇準待烟散而眇放與不快等因之殫其心思創出無烟火葯甚為合用較之他砲尤為利器矣無論何等快船雷艇縱任意奔馳亦不能逃其砲彈之外故臨海諸國爭欲有之其葯之益不但施放無烟而速率且大較之栗色餅葯每秒鐘速行二百碼達譬如十二生的之砲用栗色餅葯可擊遠一萬千餘碼達若用無烟葯則擊遠更多一萬碼達之數蓋克鹿卜能造四生的至十六生的口徑之快

Figure 10: *Illustrated Treatise on the Krupp Quick-Firing Guns* co-authored by Schnell and Duan (1890).

Retired German Army captain Constantin von Hanneken, a compatriot of Gustav von Detrin (1842–1913), who held the post of Tianjin Customs Commissioner, went on to become von Detrin's son-in-law and worked in the mining industry in China. In 1879, both von Detrin and Li Fengbao recommended the young von Hanneken to Li Hongzhang, who at that time was building up the navy. Initially employed in Li's Huai Army to train troops, von Hanneken was later appointed an instructor at the newly established Tianjin Military Academy. With Li Hongzhang's approval, he was

22 Duan Qirui was an important figure in Chinese history. He served as Premier of the Republic of China four times between 1916 and 1926, and was the *de facto* head of the Beiyang government.
23 The author remains uncertain whether the reference material utilized by Theodor Schnell was a single volume or multiple volumes of German military training manuals. Nonetheless, both Schnell and Duan Qirui incorporated content that was better tailored to the understanding of Chinese soldiers.
24 WA 3/37, HAK.

entrusted with the crucial task of building forts in Lüshun, Tianjin, and Weihai. He was also one of Li Hongzhang's contacts during his visit to Germany (von Hanneken 1998, 1).[25] He suggested to the Qing government that it should embrace Western training methods for its army (Weng [1915] 1957, 505). However, the proposal was met with criticism from the Chinese, who argued that despite his background in the German army, his extensive teaching experience in the Chinese navy made him unsuitable for the job (Zheng [1908] 2002, 420).

The dispatch of soldiers for study in Germany represented an escalation of Sino-German military cooperation, mainly coordinated by Lehmeyer and Schnell, with Li Fengbao overseeing the students in Germany. The selection of soldiers to be sent to Germany was agreed upon by Li Hongzhang and Brandt, the envoy, given their shared belief that this was necessary for mastering German military technology (Li 2008d, 366–370). Lehmeyer, who had been recommended to Li Hongzhang by von Detrin and was equally trusted by Li, had been serving as a Krupp artillery instructor in the Huai Army since 1873. In 1876, Lehmeyer led a group of seven young gunners to study in Germany, which included Bian Changsheng 卞长胜, Zhu Yaocai 朱耀彩, Wang Desheng 王得胜, Zha Lianbiao 查连标, Liu Fangpu 刘芳圃, Yuan Chunyu 袁春雨, and Yang Deming 杨德明, all of whom were Lehmeyer's Chinese students. Li Hongzhang had initially hoped that they would attend a German army or navy school, but Bian and the others lacked the same level of ability. Therefore, they were assigned to a military camp in Spandau, on the outskirts of Berlin, where they received half a day of military training and half a day of German language learning (Li 1998, 4323–4324). Months later, Bian, Zhu, and Yang were dispatched to the Bochum Association for Mining and Cast Steel Production (Bochumer Verein für Bergbau und Gussstahlfabrikation) for an internship in the workshop. Having learned of this, Li ordered that they be relocated to the Krupp factory for a more suitable internship (Li 2008e, 25–26). Wang Desheng went on to study in the German navy and army, as arranged by Li, and after Wang's return to China in 1881, Li was convinced that he had acquired German tactical techniques (Li 2008i, 380–381). All except Zhu, who had passed away in Germany, returned to China by 1878. Comparatively speaking, the team led by Schnell to Germany fared better. In 1889, Schnell led five gunners, including Duan Qirui, Wu Dingyuan 吴鼎元, Shang Dequan 商德全, Kong Qingtang 孔庆塘, and Teng Yuzao 藤毓藻, to enroll at the Military Academy Berlin (Militärakademie Berlin), where they underwent theoretical training for about half a year. Duan Qirui and his companions then interned at the Krupp artillery factory for six months, learning about shell processing, gun barrel boring, and rifling grinding, among other production processes. They also had the opportunity to practice shooting

25 Familien-Archiv Hügel, FAH II B363d, HAK.

at the Kruppschen Schießplatz Meppen shooting range (Figure 11) (Harnisch 1999, 57–58). It is noteworthy that the Krupp company highly valued the arrival of these Chinese students. Lehmeyer also took them to visit the Krupp factory in Essen,[26] which was interested in establishing connections and provided each of them with sponsorship of 2880 marks (Yu 2007, 402; Ratenhof 1987, 81).

Figure 11: Chinese artillery students at Kruppschen Schießplatz Meppen (1890).[27]

The majority of the instructors who came to China adopted Chinese names, but the commands they taught the Chinese troops were in Western languages such as German. However, most of the Chinese soldiers were still far from achieving a satisfactory grasp of modern weaponry and their tactical applications. In 1895, Baron von Reitzenstein was invited by Zhang Zhidong to the Hubei Military Academy, along with thirty-five other Germans. Their approach to training Chinese soldiers differed from that of Schnell and Li Hongzhang. Von Reitzenstein emphasized not only battlefield training but also education in mathematics, surveying, and weapon principles. The Chinese then compiled some of the teaching materials into an eighteen-*juan* treatise titled *Western Drill of the Self-Strengthening Army* (*Ziqiangjun Xifa leibian* 自强军西法类编), which was subsequently promoted in the military. The book expounded on the structure, principles, and use of Krupp artillery. The content was not only relatively systematic but also elucidated in simple Chinese, thereby facilitating teaching and training in Chinese military academies.

Missionaries in China also engaged in translating Krupp technical materials, which exerted a significant social impact. The Translation Department of the Jiangnan Arsenal, established in 1868, undertook the translation of ten of Krupp's works between 1870 and 1875, all of which were officially published. According to Zeng Guofan ([1908] 2016, 345), who was responsible for the matter at that time, translation was the bedrock for manufacturing, which must start with illustrated treatises. Li Hongzhang concurred

26 Familien-Archiv Hügel, FAH2B 363d, 21, HAK.
27 WA16e, 13, HAK.

with Zeng's view and proposed that works on artillery and manufacturing were among the most important categories (Li 2008j, 413).

On Replicating the Krupp Guns (*Kelubo pao shuo* 克虏伯炮说), translated by Carl Kreyer (1839–1914) and Li Fengbao, is representative of such translations. Kreyer was a German-American who moved to the United States with his family after completing high school. In 1865, he graduated from the Divinity School of the University of Rochester and embarked on a career as a Baptist missionary in China. In 1869, he was invited by the British missionary John Fryer (1839–1928) of the Translation Department to contribute to the translation effort. Kreyer initially delivered oral translations in Chinese, with Li Fengbao then assisting in organizing the written Chinese version.

The origin of *On Replicating the Krupp Guns* can be traced back to the German manuals of Krupp products and the training manuals for Prussian gunners. Therefore, the content of the book mainly focused on the characteristics and operational steps of Krupp artillery (Figure 12), and hardly touched upon technical details such as raw material parameters, design of the gun barrel and carriage, production processes, the calculation of firing tables, and artillery shooting trials at the firing range. Precise comprehension of the artillery tables requires some knowledge of modern trigonometry and external ballistics, but the book lacks an introduction to these principles. Importantly, the translators created some novel terms, such as rendering Krupp's wedge-shaped breech-block as "round-splitting gun door" (*yuanpi paomen* 圆劈炮门), attempting to explain trajectory using the traditional Chinese *gougu* procedure (*gougu shu* 勾股术) (Kreyer and Li 1872), and labeling the illustrations with Chinese characters corresponding to the German (Figure 13).[28] The translation of some content in the book is relatively awkward or inaccurate, reflecting the limitations of the translators' knowledge. At that time, the pertinent disciplines in China were not yet established, and knowledge of modern science and technology was still at the stage of sporadic introduction. For both missionaries and Chinese intellectuals, much of the content covered in *On Replicating the Krupp Guns* was far beyond the existing traditional knowledge system, making it difficult to comprehend. Nevertheless, this did not prevent ordinary Chinese readers from getting the gist of the characteristics of Krupp artillery and even Western-style artillery. The lack of systematization and completeness in these Chinese translated works hindered them from being directly used for actual military training, and it was almost impossible to replicate the guns by following the drawings. Nonetheless, Li Hongzhang, Zuo Zongtang, Zhang Zhidong, and others still praised these types of translated works highly and recommended their distribution and promotion to various military camps (Guo 2018, 616; Li 2008a, 19).

28 *The Krupp Quick-Firing Gun Manual* (*Kelubo kuaipao shuomingshu* 克虏伯快炮说明书), LS1. 13-7, 122, Hubei Provincial Archives.

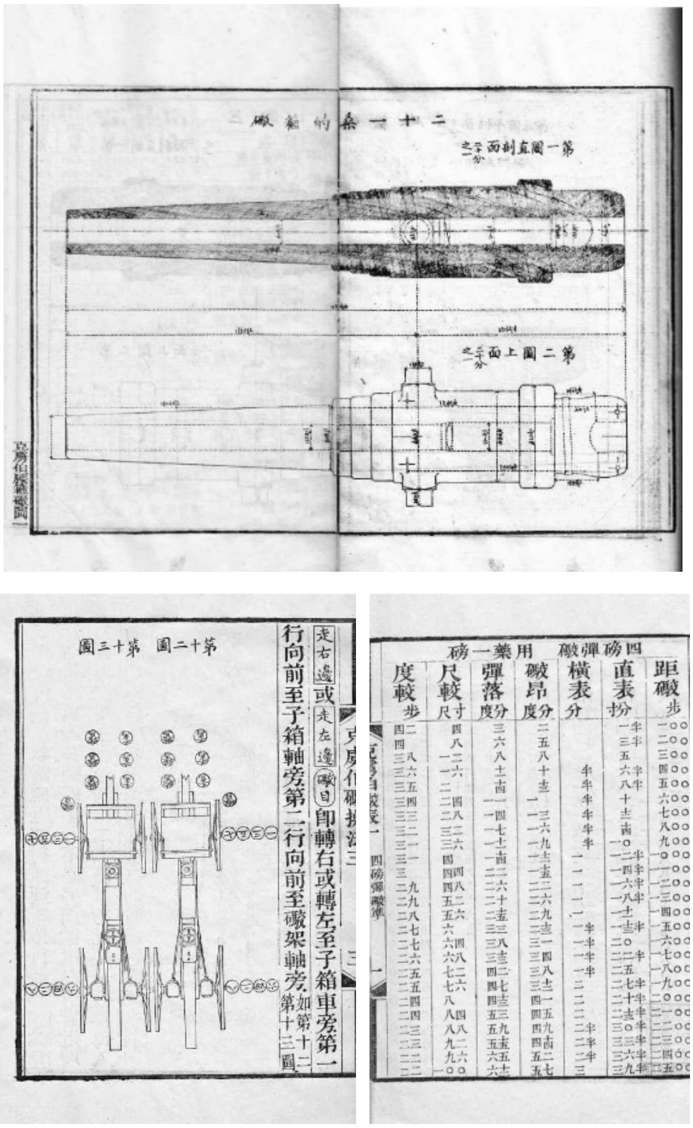

Figure 12: A Krupp manual translated into Chinese (Kreyer and Li 1872, 1, 3).

The deployment of artillery spread across a variety of military concerns, including naval vessel procurement, fort design and construction, and weapons operation and maintenance. At the inception of the Beiyang Fleet, Li Hongzhang and others were preoccupied with procurement, disregarding training. The acquisition of a diversity of ordnance led to a proliferation of technological sources, necessitating more time for trial and error. Most of the main guns on board ships were Krupp artillery, while the secondary guns consisted of both Krupp and British and French artillery. Both the *Zhiyuan* 致远 and *Jingyuan* 靖远 cruisers employed Krupp's dual main gun, albeit with the carriage made by Armstrong. During actual combat, there

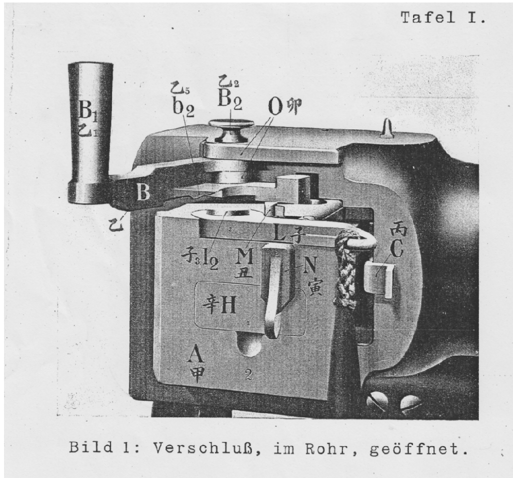

Figure 13: The breech-block illustrated in the manual of the Krupp 75 mm gun.[29]

were regular instances where the ammunition provided did not correspond with the cannon, or where the caliber of the two did not match (Weihai Municipal Committee 1990, 172). The Beiyang Fleet encountered further predicaments in the use of weapons. For example, they initially placed too much emphasis on the power of single-shot shells, overlooking the significance of firing rate. In 1894, Li Hongzhang realized that although the artillery on capital ships such as *Zhenyuan* and *Dingyuan* were newly procured, they were already old-fashioned (The First Historical Archives of China 1982, 124–125). Thus, at the time when the Beiyang Fleet was planning to purchase fast-firing guns, the Japanese navy, with its superior firing rate and flexible tactics, defeated their Chinese opponents who were fixated on the quantity and caliber of cannons.

At that time, the efficacy of cannons on land primarily hinged on their fortified emplacements. While expanding the scale of naval artillery, within little more than a decade China expeditiously constructed a large number of European-style gun emplacements, deploying both purchased and self-made artillery. Von Hanneken, Ilgner, and von Reitzenstein all guided the design and construction of gun emplacements. Von Hanneken, in particular, was directly responsible for several of the most crucial forts, such as those at Lüshun, Weihai, and Dagu at Tianjin, which actually served as the gateway to Li Hongzhang's Beiyang Fleet and the Qing Empire's capital. The configuration of the weaponry at these forts encountered a conundrum similar to that of the ships—a plethora of types of cannons. Taking the South Dagu Fort in Tianjin, which was built with significant investment, as an example, it boasted a total of forty-eight cannons, eight calibers, and over a dozen models (Figure 14) (Germany Kriegsmarine Oberkommando 1903, skizze 6). Among them, the main types were the

29 *The Krupp Quick-Firing Gun Manual*, LS1. 13-7, 122, Hubei Provincial Archives.

12 cm and 15 cm SK L/40 cannons manufactured by Krupp. These cannons, originally designed for use on ships, were repurposed as coastal defense cannons during World War I in Europe. The scene depicted in the illustration below was likely the earliest instance of their use as fort cannons globally. Unfortunately, this seemingly formidable fort was razed to the ground by the Eight-Nation Alliance, including Germany, in 1900 (Figure 15) (Der Marine 2012, 82).

There are some notable dimensions to the localization of the construction of these forts. This could include diverse varieties of artillery; for instance, some rudimentary small ones for coastal defense were equipped with outdated ship cannons (Figure 16). Frequently, very little or no cement was used in the construction of the majority of newly built forts. This was because, at the time, China struggled to produce cement, which had to be imported and combined with reinforcing steel bars, rendering it prohibitively expensive. Instead, the Chinese utilized a traditional material called *sanhetu* (三合土), a mixture of lime, gravel, and fine sand, as a substitute. *Sanhetu* had been employed for centuries in the construction of city walls, river embankments, and land structures. Li Hongzhang commended this method, as it was not only convenient and cost-effective while meeting the required quality standards, but also did not shatter into hazardous fragments upon impact (Li 2008k, 488).

Figure 14: Firepower deployment of the South Dagu Fort (Germany Kriegsmarine Oberkommando 1903, skizze 6).

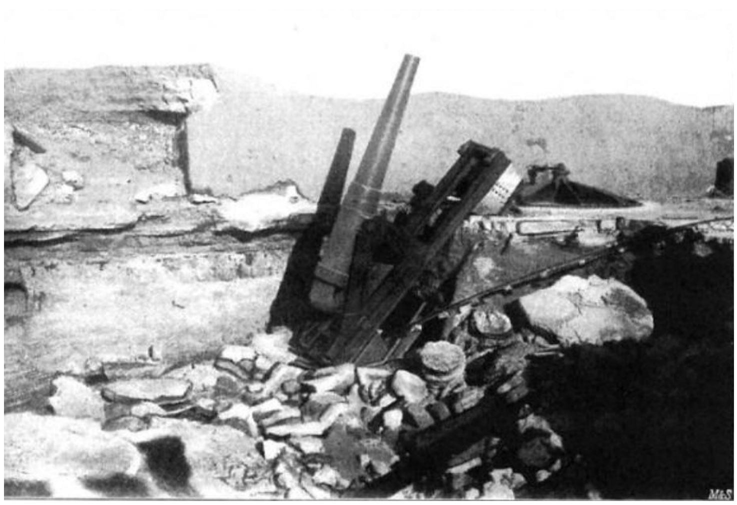

Figure 15: Destruction of Krupp cannons and forts during the war (1900) (Der Marine 2012, 82).

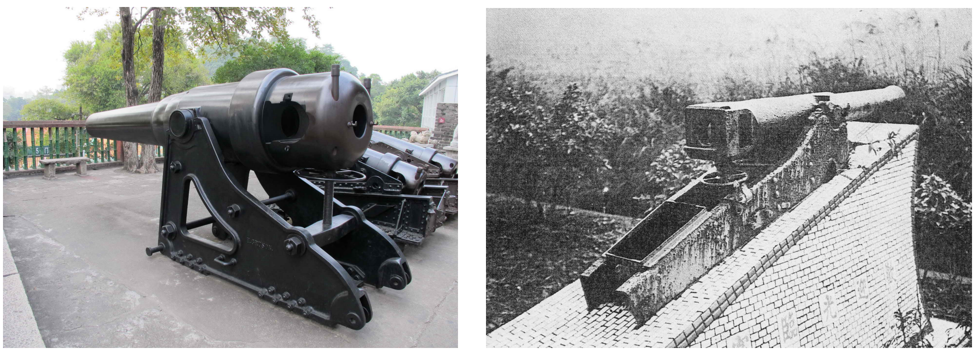

Figure 16: Ship cannons used for coastal defense (left: Guangzhou, photo by Sun Lie; right: Taiwan [Yang 1991, 389]).

Another issue was that, in practice, Chinese cannons were generally poorly maintained, with little mention in extant literature of funding or regulations dedicated to addressing this. Despite the existence of necessary maintenance procedures, shortages of spare parts, lubricants, and specialized personnel were commonplace during this period. Our investigation has uncovered several instances of such neglect, such as severe rust and corrosion found in the rifling of a Krupp cannon (Figure 17), which was likely caused by corrosion from gunpowder, rather than weathering. It is possible that gunners at the time may not have had the facilities or habits to promptly clean the interior walls of the gun after firing. Another valuable 120 mm Krupp gun was abandoned in the late nineteenth century due to jamming caused by a shell (Figure 18). Such occurrences all suggest a lack of adequate training and maintenance at that time. In contrast, in terms of logistical support, Chinese gun carriages seldom encountered transportation difficulties.

Mules, which were easier to tame, were often used instead of horses, and long-used traditional methods of traction and harnessing were readily available (Figure 6).

Figure 17: A severely corroded gun barrel (Guangzhou, photo by Sun Lie).

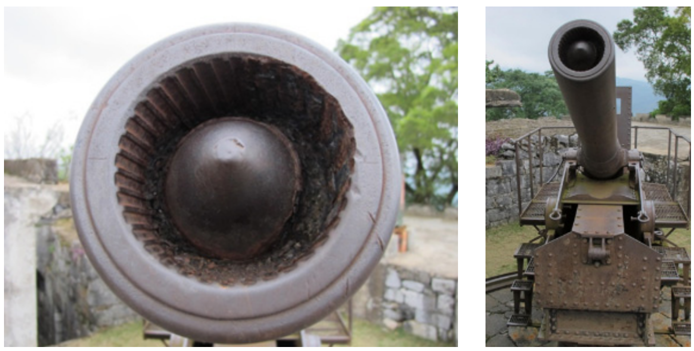

Figure 18: A 120 mm Krupp gun with a jammed shell (Guangxi, photo by Sun Lie).

5 Conclusion: Localization and the emergence of appropriate technology

Over the span of more than half a century, German Krupp technology was transferred to China through three main channels: trade, imitation, and utilization. It is clear that the recipients within China of this technology—the artillery and ammunition, arsenals and machinery, military schools, forts, and so forth—were closely linked to the donors of the technology, such as Krupp, German instructors, and engineers. The transfer process was also marked by ubiquitous changes. Given the intricate relationship between China and Germany in this case study, a transnational lens is conducive to grasping the subtle changes in knowledge within transnational networks. These changes resulted primarily from the continuous localization of technology throughout the transfer process. Some of these disparities were more aligned with China's needs or better suited to its environment, leading to the emergence of appropriate technology.

The emergence of appropriate technology through localization is not uncommon, and this case is no exception. While the impact of appropriate technology may vary between developing and developed countries, it is of equal significance (Riedijk 1984; Riedijk, Boes, and Ravesteijn 1989). The intricacy of the issue lies in the meeting of globalization with local knowledge, which can engender multiple tiers of knowledge dissemination. The knowledge referred to in this article encompasses written knowledge from books and manuals, as well as materialized knowledge embedded in machinery (Krige 2019, 1–31). Generally speaking, the so-called "new second-order local knowledge" formed through the encounter of local and globalized knowledge embodies the characteristics of tacit knowledge and is "effective in modulating the spread, appropriation and further development of knowledge"; China's trajectory to modernization "was essentially shaped by modifying globalized ideas about modernization according to specific local traditions and experiences" (Renn 2012, 383, 391, 369–397). This novel perspective is highly inspiring. Other studies have demonstrated that traditional technology and new technology, including small and large-scale technology, do not always exhibit the expected advantages, disadvantages, rights, wrongs, strengths, and weaknesses when shared in different historical contexts (Edgerton 2006). For developing countries or regions, appropriate technology itself is more adaptable to the needs of industrialization (Jéquier and Blanc 1983). In some cases, an introduced technology in technology transfer might elicit "an innovation response," culminating in a new "appropriate technology" (Pacey and Bray 2021, x, 35, 159, 228).

During the localization of Krupp technology in China, the emergence of appropriate technologies can be broadly categorized into four types of changes.

First, the shift in the source of technology transfer principally refers to the changes Krupp made to the technology for their Chinese clients. An exemplary instance of this is the design of the main guns of Chinese ironclads, which differed from those of the German navy. However, the intention of this alteration was not to enhance the Chinese main guns, especially since their firing rate remained unchanged. Instead, it was simply to accommodate the preferences of customers such as Li Hongzhang for large-caliber guns. Similarly, naval guns were converted to fort cannons, and the gun mounts were altered, though these changes posed minimal technical challenges. Krupp was indeed concerned about the needs of the Chinese side and eagerly promoted new and expensive products to them, such as the Pivot-Kannonen-boot and the Fahrpanzer. Changes in the origin of a technology will impact subsequent technology transfer processes, such as new manuals, new training, and new accessories and maintenance. During the transfer to China, the source of Krupp's technology remained relatively stable since China's primary demand was for specific types, quantities, and tonnages, and there was not a strong demand for technical details. In terms of outcomes, Krupp's continuities and changes both effectively adapted to China's rapid modernization of their military.

Second, a new environment emerged in China that was favorable for the change to new technologies. Politically and economically, the Self-Strengthening Movement during the late Qing dynasty brought about significant and profound changes to traditional Chinese society. Subsequently, modern arsenals such as the Jiangnan Arsenal, as well as a modern army and navy, emerged, which could promptly incorporate artillery and ammunition from Germany, and a sizable influx of retired German military personnel and technicians. Among these developments, perhaps even more important were novel aspects, such as the role of foreign firms, translation departments, military academies, measures to study abroad, and the adoption of ideas of individuals like Li Fengbao and Xu Jianyin. Such changes made it easier for society as a whole to accept Western science, technology, and industrial products. Two further details merit attention. Firstly, the changes in China's environment occurred as part of global changes, and the mutual adaptation between China and other countries inevitably exerted a reciprocal influence, as for instance with the impact of Japan's military changes and military exports from countries such as Britain and France on China's cooperation with Krupp. Secondly, environmental changes were not fixed but rather continued to evolve, such as the Chinese people's perception of standardization, their demand for cannons and quick-firing guns, and the sustained expansion of the populace acquiring new knowledge in China.

Third, Krupp technology instigated a shift in the mindset of many Chinese through education and training, thus changing the knowledge system of modern technology in China. The dissemination of modern technology generally requires clear educational or training channels. With the aid of the military academies, translation departments, and military camps across different regions, Krupp technology was disseminated and diffused in significant ways. Whether it was Krupp products, such as artillery and ammunition—materialized knowledge, or Krupp product manuals—textual knowledge, or even operational requirements taught by instructors—tacit knowledge, a new knowledge system centered around Krupp technology was established. Li Hongzhang, Li Fengbao, McCartney, Schnell, von Hanneken, and many new intellectuals utilized this new system to gain social recognition and make their respective contributions.

Fourth, Krupp technology underwent a significant number of adaptive changes in China, particularly in the process of imitation and implementation. The Jiangnan Arsenal manufactured Krupp replicas by means of reverse engineering. In this regard, numerous technicalities, such as materials, performance, and quality of the "Krupp-style" 75 mm mountain gun differed from the original object being emulated. Furthermore, German technical data had to be translated into Chinese, and in cross-cultural and different contexts, the fundamental knowledge, terminology system, and content expression in the corresponding Chinese translation were inevitably subject to significant variance from the German text. In this instance, Krupp basically did not directly export manufacturing technology to China, nor did it directly train Chinese engineers and workers. Nonetheless, this did not impede the localization of technology, and the occurrence of appropriate technology and knowledge. A particularly noteworthy phenomenon was that the continuation or combination of traditional Chinese technology constituted the reason for changes in the original German technology. For example, the traditional *gougu* procedure was utilized to understand ballistics, traditional harnessing methods were used to tow artillery carriages, traditional artillery was imitated to reduce shielding, and *sanhetu* was used instead of cement. These "Krupp-style" alternative technologies might not necessarily be more advanced technologies, but they were often more suitable for the local environment, simpler, more economical, and easier to understand and disseminate.

It can be said that in the context of globalization, appropriate technology exhibits a certain degree of innovation. This has been a topic of extensive discussion in recent years. "A Global Microhistory," a case study, employed the term "tinkering" to refer to the innovation that occurred in the first half of the twentieth century in Chinese chemical factories producing everyday products due to the compatibility and adjustment of existing Western knowledge and traditional Chinese knowledge (Lean 2020, 44–51). Not only in China, but in Africa different social and cultural contexts also led to gun technology more suitable for the local environment, which could also be deemed new creations (Macola 2016, 57–58). Of course, "naive innovation-centrism" in sociology reminds us that a general discussion of innovation might not be particularly engaging (Edgerton 2010). In summary, the localization of Krupp weapons during the procurement, imitation, and utilization process led to the emergence of appropriate technology in China. Although innovation has not been the focal point of this case study, it may warrant further exploration in the future.

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