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Anti-Smoke Pollution Technology and Its Conversion to Military Use in the Royal Navy in the Mid-19th Century

By MASAHIKO AKATSU*

This paper discusses two cases in which civilian knowledge and technology for preventing air pollution caused by coal smoke from factories, which was becoming a serious problem in 19th-century British cities, were applied and converted to military use (the improvement of the performance of steam-powered vessels, which were still in their infancy) by the Royal Navy in the mid-19th century. The background and processes that led to the technology's conversion to military use are also examined in this paper.

Introduction

The rapid increase in coal consumption by factories in Britain after the Industrial Revolution aggravated the problem of air pollution caused by smoke from coal combustion, which in 19th-century Britain was regarded mainly as soot (carbon) left over from inadequate coal combustion. The air pollution was mainly blamed for economic damages (defacing property, lowering land prices, wasting fuel, etc.) rather than for health hazards. Legal responses to the damages caused by soot and smoke continued to be strengthened throughout the 19th century, beginning with the enactment of the Smoke Nuisance Abatement Act of 1821. This legislation was driven by increased knowledge and technological advances to prevent or reduce smoke from coal combustion in industrial furnaces or fire chambers used to heat steam-engine boilers.[1]

Using two case studies, this paper examines the background and processes of the transformation of civilian knowledge and technology concerning smoke control (which had been created, accumulated, and used for the peaceful purpose of helping victims of smoke pollution) into military technology in the Royal Navy in the mid-19th century. As discussed later, the Royal Navy faced various problems regarding the efficient operation of steamships, which had just begun to be used at that time. In this situation, knowledge and technology related to smoke-pollution prevention for civilian use were applied to the improvement of steamships for military use. How did knowledge and technology used for smoke-pollution control become military technology? This paper aims to clarify the background and processes of such conversion and diversion.

The ambivalence regarding the use of scientific knowledge and technology for not only peaceful purposes but also military purposes is an age-old problem. Recently, however, the

* Associate Professor, School of Political Science and Economics, Meiji University

[1] See Akatsu [2003, 2005, 2010] for a discussion of smoke-pollution problems and countermeasures in 19th-century Britain.

global leakage and transfer of knowledge and technology that can be used for military purposes have emerged as particularly serious problems, and the appropriate responses to these challenges and the management of such knowledge and technology have become urgent issues.[2] Environmental knowledge and technology for the prevention of air pollution, such as those discussed here, seem distant from military activities; therefore, such knowledge and technology tend to be actively transferred to developing countries for international assistance and exchange.[3] However, as these also comprise scientific knowledge and technology, it cannot be claimed that it is not possible for them to be diverted to the military. The transfer of environmental knowledge and technology from developed to developing countries will likely be promoted more actively in the future. The author hopes that this report will help readers think about how this transfer should be done.

Historical research on the ambivalence of science and technology and on the conversion of military technology to civilian use and vice versa has advanced rapidly in recent years, with abundant results.[4] However, to the best of the author's knowledge, there is no prior research on the military conversion of civilian knowledge and technology for smoke pollution prevention in the Royal Navy in the mid-19th century, which is the subject of this paper. It would be the author's great pleasure if this paper could add new knowledge to the growing body of historical research on both military and civilian diversion of scientific knowledge and technology in recent years.

1. Use of knowledge and technology for smoke pollution prevention in the selection of fuel (coal) for naval steamships

(1) Lyon Playfair as a politician of science

The first example of the above-mentioned military applications in mid-19th century Britain is the diversion of civilian knowledge and technology related to smoke control for the selection of fuel (coal) for naval steamships. The chemist Lyon Playfair (1818–1898) played an important role in this process.

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2 For example, in recent years, the Japanese Ministry of Economy, Trade and Industry (METI) has been strengthening its measures against the outflow of technology (sensitive technology management related to security trade) that can be diverted from universities and research institutes to military use, including dispatching advisors to universities and research institutes, holding guidance and briefing sessions, and distributing leaflets and various other materials. For more information, see the "Security Trade Control" page on the METI website (https://www.meti.go.jp/policy/anpo/daigaku.html, viewed August 17, 2019).

3 For example, in December 2013, industry, government, and academia experts from Japan, China, and South Korea held a forum in Xianghe, Hebei Province, to discuss measures to deal with air pollution and other environmental problems. The Japanese participants introduced their country's anti-pollution measures since the 1970s and proposed cooperation with their Chinese colleagues in the field of environmental technology (*Nihon Keizai Shimbun*, December 15, 2013, morning edition, p. 5). In July 2013, the 8th China-Japan-South Korea Witenagemot was held in Toyako Town, Hokkaido, Japan, to discuss cooperation among Japan, China, and South Korea in the economic, political, and academic fields. Prime Minister Yasuo Fukuda, the head of the Japanese delegation, stated that ''cooperation on cross-border environmental problem is an urgent issue,'' bearing in mind the worsening air pollution problem caused by fine particulate matter in China. Additionally, in response to the many calls for stronger technological collaboration in the environmental field at the conference, he stated, ''There are many areas where industry, government, and academia can cooperate in the development of environmental technology.'' (*Nihon Keizai Shimbun*, July 8, 2013, evening edition, p. 2). In March 2013, the Japan Bank for International Cooperation, in collaboration with Sumitomo Mitsui Banking Corporation, decided to provide $90 million in loans to the Indian steel industry, with the aim of promoting the transfer of Japanese environmental technology to Indian steel mills and other facilities (*Nihon Keizai Shimbun*, March 27, 2013, evening edition, p. 1).

4 See, for example, Yokoi and Onozuka [2012], Yokoi [2016], Ikeuchi [2016], and Kawamura [2018].

Born in India and the son of George Playfair (a medical superintendent of the East India Company and a member of an old Scottish family), Lyon studied medicine and chemistry at the universities of St. Andrews and Edinburgh. In the 1830s, he worked under the tutelage of Thomas Graham, the famous inventor of the law of gas diffusion and the dialysis membrane, and the German organic chemist Justus Freiherr von Liebig.[5] Around 1843–1845, as an honorary professor at the Royal Manchester Institution, he worked with the chemist Robert Angus Smith, who would later become famous for his efforts in countering the problem of toxic fumes from copper refineries and chemical plants.[6] Around this period (1844), he also collaborated with Robert Wilhelm Eberhard Bunsen, a prominent German chemist and burner improver, on the combustion of coal (coke) and its efficiency in blast furnaces.[7] Although Playfair's specialty appears to be organic chemistry, his joint research with Bunsen suggests his initial expertise in the combustion of coal and other materials. He also collaborated with Josiah Parkes, a worsted manufacturer who developed the early smoke-control furnaces with the help of Sir Humphry Davy, a developer of safety lamps for coal mines and one of the leading figures in science and technology, and probably with Prime Minister Robert Peel. He became acquainted with Parkes around 1845, probably through his friendship with Peel.[8]

Notwithstanding Playfair's career as a scientist, he was deeply involved in politics; his biographer later described him as one of the "statesmen of science" in the 19th century.[9]

First, he had a fairly close relationship with Peel, although it is unclear how this came about. He was often invited to meetings at Drayton Manor, Peel's residence in Staffordshire, and his acquaintance with Parkes was made during these meetings. He also served on government committees. As mentioned later in this paper, from 1843 to 1845, he was a member of the Commissioners for Inquiring into the State of Large Towns and Populous Districts.[10] Furthermore, during the Irish potato famine, as a chemist, Playfair was asked by Peel to advise him and was said to have had some influence on policy decisions.[11] At the Great Exhibition of the Works of Industry of All Nations in 1851, he was a member of the organizing committee and played an important role as a liaison between the committee and the government.[12] In his capacity as Secretary of the Science Department of the Privy Council, he also advocated the use of poison (cyanide) and phosphorus incendiary shells to the government during the Crimean War of 1853–1856.[13]

He became a member of the House of Commons for the constituency of the universities of Edinburgh and St. Andrews (1868), Postmaster General and Privy Councillor in Gladstone's cabinet (1873), Deputy Speaker of the House of Commons (1880), and in 1892, he was knighted and became the first Baron Playfair of St. Andrews.[14]

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5 Crowther [1965], pp. 109–116; Reid [1899], pp. 28–52.

6 Reid [1899], p. 56.

7 Reid [1899], pp. 62–63.

8 House of Commons Parliamentary Papers (hereafter, HCPP), Report from the Select Committee on Smoke Prevention, 1843, pp. 158, 165; Crowther [1965], p. 132.

9 Crowther [1965].

10 Crowther [1965], pp. 128–130.

11 Reid [1899], p. 87; Crowther [1965], pp. 132–133.

12 Crowther [1965] pp. 134–135.

13 Crowther [1965], pp. 140–142. Thus, Playfair was an active advocate of the military use of science (chemistry). He was also involved in the restoration of the honor of Thomas Cochrane, 10th Earl of Dundonald, a Scottish nobleman, inventor, and naval admiral, who had advocated the military use of chemistry in the Napoleonic Wars but lost his honor due to a false charge of fraud in connection with stock trading. Playfair is said to have supported in principle the use of science to improve military weapons (Crowther [1965], p. 149).

14 Crowther [1965], pp. 144–154; Reid [1899], p. 218.

(2) Playfair and De La Beche's research on smoke pollution problem

Here is how Playfair, a chemist with close ties to politics and considerable knowledge of coal combustion, became involved in the smoke pollution problem and the smoke preventing technologies.

As previously mentioned, Playfair became a member of the Commissioners for Inquiring into the State of Large Towns and Populous Districts established by Peel's cabinet in 1843. The commission members were the chairman of the commission and Lord Privy Seal, Walter Francis Montagu Douglas Scott (5th Duke of Buccleuch); First Commissioner of Woods and Forests, Henry Fiennes Pelham-Clinton (the Earl of Lincoln); geologist Sir Henry Thomas De La Beche (1796–1855); biologist and comparative anatomist Richard Owen; engineer and "Father of the Railroad" George Stephenson; and Playfair. Playfair, an emeritus professor at the Manchester Royal Institution, was responsible for researching and reporting on the living and sanitary conditions of the metropolis of Lancashire, with the previously mentioned Smith as his assistant.[15]

Incidentally, in the very same year that the Commissioners for Inquiring into the State of Large Towns and Populous Districts was established, the Select Committee on Smoke Prevention was formed by William Alexander Mackinnon, a member of the House of Commons. The committee conducted a fairly thorough inquiry into the air pollution caused by coal smoke in British cities and the technical and legal responses for its prevention or reduction. Based on his findings, Mackinnon submitted the Bill to Prohibit the Nuisance of Smoke from Furnaces or Manufactories to the House of Commons in 1844 and 1845. However, the bill was repealed due to differences and conflicts of interest among the various industries that were required to take measures against smoke pollution.[16] Recognizing the importance of the issue, Peel's cabinet decided to proceed with a government investigation of the problem of smoke pollution in large British cities, independently of Mackinnon and his committee.[17]

In August 1845, Sir James Robert George Graham (Home Secretary) instructed the Earl of Lincoln (First Commissioner of Woods and Forests) to investigate the matter. Based on this directive, the Earl of Lincoln appointed De La Beche and Playfair to conduct the actual investigation.[18] At the time of the request, De La Beche was the director of The Geological Survey and the director of The Museum of Economic (or Practical) Geology, and Playfair had just moved to London from Manchester to work as an appointed chemist under De La Beche, through Peel's arrangement.[19] They were chosen as investigators because they were not only experts in coal and its combustion as a source of air pollution but had also worked together on the Commissioners for Inquiring into the State of Large Towns and Populous Districts. According to the Earl of Lincoln's request for research, Playfair "was known to have already directed [his] attention" to smoke pollution issues. Playfair's and De La Beche's investigation reports were submitted in March 1846 to Viscount Charles John Canning, First Commissioner of Woods and Forests, who had replaced the Earl of Lincoln

15 Crowther [1965], pp. 128–130.

16 For more information, see Akatsu [2005].

17 In debating on Mackinnon's bill, Peel asked, "all persons connected with the manufacturing districts, and who were anxious for the health of the towns with which they were connected, would turn their attention to the subject [of smoke pollution]." He also stated that if Mackinnon would withdraw his bill in the meantime, he [the government] would present it in a better form in the next session (Parliamentary Debates, July 3, 1844, c. 285).

18 HCPP, Report by Sir Henry Thomas De La Beche and Dr. Lyon Playfair on means of obviating evils arising from smoke by factories and works in large towns, pp. 1–2.

19 Crowther [1965], p. 130.

at the end of the term of Peel's cabinet.[20]

In their report, Playfair and De La Beche first theoretically explained the mechanism of smoke generation as follows: coal smoke is basically carbon, which is released from the chimney when coal is only partially combusted due to insufficient oxygen supply in the furnace or fire chamber, caused by improper management, among other reasons. They then conducted a series of coal combustion experiments and concluded that smoke control was possible only through complete combustion of coal. They suggested the installation of furnaces, flues, and chimneys designed to ensure sufficient ventilation or air supply to the furnaces, as well as appropriate guidance and education for furnace managers. If these measures were properly implemented and sufficient air was supplied to the furnace or fire chamber to ensure complete combustion of coal, it would not only theoretically and practically eliminate smoke but also improve combustion efficiency and conserve fuel. They then studied the law enforcement situation in localities such as Derby, Leeds, Huddersfield, and Manchester, which had already implemented local acts containing smoke clauses, and found that smoke pollution in large cities was not adequately prevented for technical reasons, but mainly due to inadequate laws and lack of enforcement.[21]

(3) Naval steamship fuel (coal) survey by Playfair and De La Beche

In June 1845, shortly before Playfair and De La Beche were asked by the Earl of Lincoln to investigate the problem of smoke pollution in the city and its countermeasures, Joseph Hume, a member of the House of Commons, proposed to the Admiralty that a study of the steam-generation capacity and combustion efficiency of various types of coal produced in Britain be conducted. Hume had doubts that the Admiralty had previously awarded a supplier's (Mr. Grants') artificial fuel (e.g., perhaps coal briquettes) as suitable fuel, presumably for naval steamships. Probably, he was concerned about using such artificial fuel, which was problematic in terms of stable supply and cost, for steamships. Believing that the quality of fuel was crucial for the efficient operation of steam warships, Hume cited a similar study conducted in the United States earlier, claiming that the results would be of "great national importance ... at a moment when the greatest interests of the country may be at stake."[22]

In making the proposal, Hume appointed Playfair and De La Beche to conduct the study. Hume's reason for doing so is unclear; however, he was a Scottish physician and chemist before he was a member of the House of Commons. Possibly, he had some connection with Playfair, whom Hume described as "one chemist of eminence".[23]

The Admiralty granted Hume's request and asked the Earl of Lincoln to act as intermediary to De La Beche. De La Beche accepted the request on condition that the Admiralty pay £600 in aid for the survey up to the end of March 1846.[24] De La Beche and Playfair were undertaking two government-related jobs related to coal burning at about the same time.

Their protracted investigation of coal for naval steamers lasted until around March 1851. The reports were submitted in triplicate to Viscount Morpeth (George William Frederick Howard), the Earl of Carlisle (the same Viscount Morpeth mentioned above), and Lord

20 HCPP, Report by Sir Henry Thomas De La Beche and Dr. Lyon Playfair on means of obviating evils arising from smoke by factories and works in large towns, pp. 1–2.

21 HCPP, Report by Sir Henry Thomas De La Beche and Dr. Lyon Playfair on means of obviating evils arising from smoke by factories and works in large towns, pp. 2–6.

22 HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair, p. 3.

23 HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair, p. 3.

24 HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair, p. 4.

Seymour (Edward Adolphus Seymour), all successive First Commissioner of Woods and Forests after the Earl of Lincoln.[25] The following is a summary of their research that can be gleaned from the reports, which total a considerable number of pages.

For its experiments, they borrowed a boiler and a furnace at the College for Civil Engineers in Putney, which were installed there by John Willson, Principal of the Royal Agricultural College of Cirencester. With Willson, John Arthur Phillips, a student at the École des Mines of Paris, and others as assistants, the team produced 110 major types of coal (including artificial fuels) from all over the United Kingdom, including 37 from Wales (mainly South Wales), 18 from Newcastle (Durham, Northumberland, and other northeastern counties), 8 from Derbyshire, 28 from Lancashire, 8 from Scotland, 1 from Ireland, 4 from other England countries, 6 artificial fuels. The experiments were conducted by burning the coal in a furnace and generating steam (in a boiler). They also analyzed the chemistry of the coal with the assistance of others, including Francis Wrightson, who, like Playfair, was Liebig's student.[26]

In selecting the preferred fuel for naval steamships, the following factors were of particular importance, in the order listed in the report: "a quick production of steam", "large evaporative powers", "a smokeless combustion", "a capacity for stowage in small bulk", "the power of resisting attrition", and "a freedom from the qualities that tend to produce spontaneous combustion".[27] The fuel (coal) should have good performance on these research items to enable the efficient operation of naval steamships at that time.

During the survey period, the main propulsion device of naval steamships was the outer paddle wheel, not the screw propeller as seen in the picture of the paddle sloop *HMS Driver* (Figure 1). As also shown in Figure 1, these ships had sails and were driven not only by steam power but also by wind power. As the very first steam warship, it naturally faced various operational problems that differed from those of sailing ships.

First, such steamships required heavy steam engines and boilers, as well as coal, a bulky and costly type of fuel. This was a major disadvantage in ship operation that sailing ships did not have, and to operate effectively, military advantages, including long-distance sailing in no-wind conditions and high-speed sailing during combat, needed to offset the disadvantage. There is no doubt that the survey items that reflect these factors are "a quick production of steam" and "large evaporative powers". Combustion efficiency, which is an economic (fuel cost) issue in the civilian world, also became a challenge to the freedom of military action by the Royal Navy. The improvement of combustion efficiency (adoption of coal with high combustion efficiency) brought military advantages to steamships that sailing ships lacked (more freedom of military action, not restricted by winds) and had the potential to solve the problems of steamships.

A major problem peculiar to steamships that was not found in sailing ships was the emission of coal smoke. The fact that "smokeless combustion" was listed as the third most important survey item, following "a quick production of steam" and "large evaporative powers", clearly indicated its recognition as an important issue for steamship operations in the Royal Navy. Why then was smoke emission a problem for naval steamships, and why was smokeless combustion necessary? The stated reason was "as to betray the position of

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[25] HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair; HCPP, Second report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair; HCPP, Third report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair.

[26] HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair, p. 6.

[27] HCPP, Third report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair, p. 3.

ships of war when it is desirable that this should be concealed."[28] Unlike sailing ships, steamships emit smoke, making them more susceptible to detection by the enemy. In the civilian world, smoke is harmful to others and therefore must be prevented, but in the navy, smoke control is required to ensure secrecy during steaming. If a less smoky fuel (coal) could be found, it would solve a major problem in the military operation of steamships.

In summarizing the results of their experiments and investigations, De La Beche and Playfair did not state their findings explicitly but presented various figures (tables) and remarks and generally gave high marks, especially to South Welsh coal, among many other coals.[29] South Welsh coal had a variety of characteristics, ranging from bituminous coal (but most of South Welsh bituminous coal contained less bitumen than other general bituminous coal) to anthracite (which had very little bitumen and was highly carbonized). Anthracite was not highly valued because despite its steam-generating power, it was difficult to ignite and had major problems in the speed of its steam generation.[30] Highly regarded South Welsh coals, such as the "Aberaman Merthyr" from the Aberaman Valley in Glamorganshire (very high combustion efficiency and very little smoke)[31], "Thomas' Merthyr" from Letty Shenkin in Glamorganshire (which burned very efficiently, and although not specifically mentioned, seemed to have produced very little smoke as there was very little soot in the flue)[32], and "Nixon's Merthyr" from Werra near Merthyr Tydfil in Glamorganshire (which burned efficiently and was almost smokeless)[33] were not anthracite.

South Welsh coal, which was considered the best fuel for naval steamships because of its high combustion efficiency and low smoke emission, became an important fuel for the Royal Navy in practice. According to "The Supply of Welsh Steam Coal for Naval Use", a document distributed to Balfour's cabinet in 1905, "smokelessness" and "general efficiency of steam raising" were important requirements for the Navy when purchasing coal. No other coal satisfied these requirements as well as coals from South Wales (Glamorganshire and Monmouthshire). The stable supply of South Welsh coal had been threatened by depletion and by foreign (German, American, etc.) syndicates' attempts to acquire coal mines, which was why that document had been prepared for the cabinet.[34] South Welsh coal had become a strategic commodity of such "national importance" that its stable supply was discussed at cabinet meetings.

It is well known that South Welsh coal (also called Cardiff coal) became an important strategic commodity for Japan as well. During the Russo–Japanese War, the United Kingdom provided Cardiff coal to Japan (their ally) but restricted its supply to Russia, as it was already in demand by navies worldwide as fuel for steamships. It was reported that the Baltic Fleet, which lacked access to sufficient Cardiff coal, chose the shortest route from Kamran Bay to Vladivostok over the safer Pacific route, the Sea of Japan, which would have led to a major defeat in the Battle of the Sea of Japan.[35]

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28 HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair, p. 17

29 HCPP, Third report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair, pp. 3–10.

30 HCPP, First report on the coals suited to the steam navy by Sir Henry de la Beche & Dr. Lyon Playfair, p. 17.

31 HCPP, Third report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair, p. 26.

32 HCPP, Second report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair, p. 37.

33 HCPP, Second report on the coals suited to the steam navy by Sir Henry De La Beche and Dr. Lyon Playfair, p. 41.

34 National Archives (CAB 1/6/1), The Supply of Welsh Steam Coal for the Navy, pp. 1–7.

35 Yamazaki [2008], pp. 51–75.

Playfair and De La Beche's knowledge and the technology of coal and its combustion were used (as described above) for the peaceful purpose of combating the problem of smoke pollution from coal smoke, as well as for the military purpose of improving the performance of naval steamships. On one hand, these knowledge and technology were employed to demonstrate the improved combustion efficiency (fuel savings) associated with smoke control in order to prevent smoke pollution in the civilian world and to achieve smoke pollution control that would not be too burdensome on manufactures. On the other hand, it was used in the Royal Navy to enable long-distance navigation in no-wind conditions and high-speed navigation during combat, increase freedom of military action, and ensure secrecy during steaming. The same knowledge and technology were applied for both civilian and military purposes by changing their objectives and meanings and by undergoing a military semantic shift.[36]

3. Use of smoke-preventing fire chamber in naval steamship

(1) Navy and smoke-preventing furnace

The second example of the transfer of knowledge and technology (related to smoke pollution control) to military and naval applications involved the fire chambers used to heat boilers for naval steamships. In the mid-19th century, the Royal Navy researched various types of smoke-preventing furnace (it was called at that time "smoke consuming furnace", "smoke consuming apparatus", "smoke preventing furnace", etc.) for civilian use, as well as for military purposes, mainly for preventing smoke to ensure secrecy during steaming. In particular, some of these smoke-preventing furnaces and apparatuses were actually employed in the Navy arsenal.

Perhaps the first historical record that shows the Royal Navy's involvement in the smoke-control furnaces or fire chambers is the transcript of the testimony in the Report from the Select Committee on Smoke Prevention, as cited in the previous section. At that committee hearing, Sir William Edward Parry, a Navy Captain and Comptroller of Steam Machinery for the Navy, and Thomas Lloyd, Chief Engineer and Inspector at Woolwich Dockyard, were asked to testify about their experiences in the Navy's steam industry. Lloyd provided much testimony about the smoke-suppressing furnaces or fire chambers being tested and installed on naval vessels and at naval arsenals.

Many witnesses (mainly manufacturers engaged in the textile industry) who were subpoenaed for this committee hearing and were using smoke control furnaces and boiler chambers testified about the effectiveness of these furnaces in controlling smoke and in saving fuel.[37] However, the naval engineers' testimonies here mainly focused on the smoke-control effects of the furnaces or fire chambers, and it can be inferred that the purpose of their trial and introduction was mainly for smoke control rather than fuel savings.

John Chanter's smoke-control fire chamber was the first to be introduced to naval vessels. Based on the theory at that time, smoke was generated by partial combustion of coal

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36 The Playfair and De La Beche reports on the naval steamship coal survey are preserved not only as parliamentary documents (HCPP) but also as government files at the National Archives. The repository comprises the archives of the Ministry of Railways (RAIL1059/2), originally housed at the Great Western Railway's archive center. This suggests that the results of Playfair and colleagues' survey on fuel (coal) for naval steamships may have been used to study fuel for steam locomotives. It is also possible that the military knowledge was already being used for civilian purposes.

37 For more information, see Akatsu [2005].

without sufficient oxygen supply to the furnace or fire chamber. Chanter's boiler fire chamber had additional air inlet points to supply more air to the fire chamber, aside from the fire bars (fire-grate), which were the original air inlet points to the fire chamber. Many of other similar smoke-control furnaces were based on the same principle. His smoke-preventing fire chamber was installed on *HMS Pluto*, a paddle gun navy vessel. It successfully prevented smoke but was considered difficult to handle and install in the required space.[38] According to Chanter himself, in civilian vessels, it had been used on *the Enterprise*, *the Avon*, and *the Severn* to high acclaim.[39]

Next, mention was made of Joseph Williams' smoke-preventing fire chamber (with a tube for preheating incoming air as a not-so-common feature). The same fire chambers were introduced in the Navy, on *HMS Urgent* (2-gun paddle packet), *HMS Merlin* (2-gun paddle packet), *HMS Driver* (paddle sloop), and *HMS Shearwater* (2-gun paddle packet). As with Chanter's newly designed fire chamber, it seemed to have successfully prevented smoke, but Parry stated that he received reports of various difficulties, including melting of the tubes for air preheating.[40] Next, he introduced the newly designed fire chamber by Samuel Hall (which also had a pipe for preheating incoming air). The fire chamber was installed at *HMS Megaera* (paddle sloop) and *HMS Shearwater* and had been generally successful in controlling smoke.[41]

The above was the smoke-control fire chamber actually introduced in naval vessels, but there was also mention of the smoke prevention fire chamber by Charles Wye Williams (c.1780–1866), which was generally highly regarded for both land and shipboard uses by the Select Committee on the Smoke Prevention. There was also a reference to Parry, who described Williams as the most knowledgeable man in England, both theoretically and practically, on the subject of smoke control for marine steam engines, and also presumed that his boiler fire chamber was excellent. At this point, however, the Royal Navy had not tried Williams' boiler fire chamber.[42] Nonetheless, as discussed in more detail in the next section, his new design for the boiler fire chamber was later tested by the Navy.

Testimonies on furnaces that were tried and used on land-based steam boilers at the Woolwich Dockyard included Richard Rodda's newly designed furnace and George Godson's smoke-prevention furnace. The principle of Godson's furnace was quite different from that of the other newly designed furnaces. Although Godson's furnace was designed to supply sufficient air inside it, the fire-grate was the air inflow point, which was the original one. The fire-grates were often clogged due to the large amount of coal burned on them, which prevented sufficient air from flowing into the furnace, causing partial combustion and smoke generation. Therefore, a device was installed in Godson's furnace to provide a stable supply of coal to the fire-grate and to pretreat (coking) the coal being fed so that the fire-grate would not become clogged and the coal would burn more easily.[43] Other similar furnaces that were not tested at Woolwich Dockyard but were examined onsite included Ivison's newly designed grate (with the unusual feature of allowing high-pressure steam from the boiler to flow into the fire-grate) and John Juckes' revolving grate (a certain amount of coal is dropped from a hopper onto a gently rotating caterpillar-like fire-grate). All of these furnaces successfully prevented smoke but required a large space

38 HCPP, Report from the Select Committee on Smoke Prevention (1843), p. 108.
39 HCPP, Report from the Select Committee on Smoke Prevention (1843), pp. 121–122.
40 HCPP, Report from the Select Committee on Smoke Prevention (1843), p. 110.
41 HCPP, Report from the Select Committee on Smoke Prevention (1843), p. 111.
42 HCPP, Report from the Select Committee on Smoke Prevention (1843), p. 110.
43 Mudie [1841], p. 109; HCPP, Report from the Select Committee on Smoke Prevention (1843), pp. 95, 112.

for installation, were complex in design, and had durability problems, making them unsuitable for application to steamships.[44]

The stable coal-feeding furnaces and newly designed furnaces with some complicated mechanisms, which were used on land and probably required considerable installation space, were also difficult to employ in steamships. However, many other newly designed furnaces, believed to be originally intended for land use, appeared to have been easily converted for steamship use without any mention of major modifications. The probable reason was that marine boilers at that time were fire-tube boiler with high water retention capacity and low atmospheric pressure, and unlike the later-generation water-tube boilers with high temperature and high atmospheric pressure, the installation space was as large and the mechanism was not as complicated as those of land-based boilers used in factories, among others. It was believed that unlike the later-generation water-tube boilers, there was no major difference in installation space or mechanism between the marine boiler and the land-based boiler used in factories. It was thought that because steamships, marine steam engines, and marine steam boilers were still in their infancy, the land-use smoke-suppressing furnaces to prevent smoke pollution were converted directly for application in steamships as a temporary measure. Undeniably, this also served as an important background for the military conversion of civilian-use smoke-preventing furnaces during this period.

As described above, the Royal Navy had been testing many of the furnaces or fire chambers developed for the purpose of preventing smoke pollution, mainly for smoke control, and some of them had even been introduced to naval steamships. The reasons behind their trial use and introduction in the first place were not clear from the testimonies. One possibility was that first of all, the Navy might have been sued for smoke nuisance. In fact, in 1859, the City of Liverpool complained to the Admiralty about smoke from Navy (Coast Guard) steamer (*HMS Sea Mew*) navigating on the River Mersey.[45] However, this incident occurred long after the Navy's trial and use of the smoke-preventive fire chambers described above, and no such complaints or lawsuits can be found in the main historical records prior to 1859 and probably never even existed.

Another possibility involved an experiment to prevent smoke on the Queen's yacht, which was *HMY Victoria and Albert*, launched in 1843. Managed by the Navy, she was the first paddle royal yacht. However, the prevention of smoke and soot emitted from her huge funnel (chimney) was a major problem in the Navy, probably about the soot falling on the dressed royals.[46] However, this problem would be addressed by the use of the Llanelly coal from South Wales, which produced less smoke. This issue was tackled not only in the studies by Playfair and De La Beche (cited in the previous section), but Woolwich Dockyard had also conducted combustion tests on nearly 50 different types of coal as of 1843.[47]

The most probable explanation is that smoke-preventing fire chambers were tried out and introduced for the military purposes of preventing the generation of smoke and ensuring secrecy during steaming. The trial use and introduction of the smoke-suppressing fire chambers occurred at around the same time as Playfair and De La Beche's coal surveys that

[44] HCPP, Report from the Select Committee on Smoke Prevention (1843), pp. 109, 111–112.

[45] National Archives (TS18/80), As to Smoke from Her Majesty's Steamers on the Mersey.

[46] HCPP, Report from the Select Committee on Smoke Prevention (1843), pp. 112–113.

[47] HCPP, Report from the Select Committee on Smoke Prevention (1843), p. 126. Lloyd, Chief Engineer and Inspector at Woolwich Dockyard, who testified to this, also emphasized that the Llanelly coal was South Welsh coal but not anthracite coal, noting that the latter was difficult to burn. He also stated that the Llanelly coal had a higher carbon content and lower bituminous content than those of common coal.

emphasized the importance of smoke suppression (which would ensure secrecy during steaming) in selecting coal suitable for naval steamers (as already mentioned). It is probably reasonable to assume that the survey and trial use of the smoke-control fire chamber by the naval arsenal engineers were also conducted for this military purpose. Smoke-control technology, which had been applied to prevent smoke pollution, was converted to military use here as well. In the same period, an engineer who recommended the use of Steven's patented smokeless furnaces on naval steamers noted that the funnels could be made smaller (less conspicuous) by reducing the generation of smoke. This would lead to ball-proofing, and he explained that for this reason, it would be necessary to introduce a smoke-preventing fire chamber.[48] At this time, because smoke control was clearly found to have military utility, the smoke-suppressing fire chamber, which had been used in civilian applications to prevent smoke nuisance, was being tried out and introduced in the Royal Navy.

(2) Charles W. Williams' smoke-control fire chamber

There is another example of the Royal Navy's involvement in the civilian use of smoke-preventing furnace for smoke pollution control in the mid-19th century. Charles W. Williams' smoke-preventing fire chamber (which was mentioned in the previous section) was put to use by the naval arsenal in 1858.

Williams was the Managing Director of the City of Dublin Steam Packet Company and Director of the Peninsular and Oriental Steam Navigation Company, P&O, when he was called as a witness at the Select Committee on Smoke Prevention hearing in 1843. The committee highly evaluated his new design of the fire chamber for its effectiveness in controlling smoke and saving fuel, as mentioned earlier. His new design had been used on *the Hindostan* and *the Prince* in the private sector, but as of 1843, it had not been applied in any naval vessel or naval arsenal.

In 1858, Williams' new design for a boiler fire chamber would be tried by R. Taplin, Assistant Inspector of Steam Machinery at Woolwich Dockyard and T. W. Miller, Assistant Chief Engineer at Portsmouth Dockyard, and with the cooperation of "the Steam Collieries Association of the North of England" and "the Association for consuming the Smoke of Bituminous Coal when used in Tubular or other Marine Boilers", at Elswick, Newcastle-upon-Tyne, a prosperous coal trading town in the coalfield region of northeastern England.

The trial smoke control was conducted on Williams' boiler fire chamber (Figure 2), which was partly modified by the above-mentioned association. As shown in the figure, Williams' newly designed fire chamber had numerous air passages. The boiler for steamship used in the experiment is shown in Figure 3. As already mentioned, at that time, marine steam boilers were fire-tube boilers or tubular boilers with high water retention capacity but low atmospheric pressure, as shown in the above association's name and in Figure 3; water-tube boilers with high temperature and high atmospheric pressure had not yet made their appearance. In this trial experiment, the feed water preheater, probably an advanced technology at that time was also attached to the boiler and used. Forced draught using a steam jet was also attempted.

As shown in Table 1, the main factors investigated during the trials involved combustion efficiency, such as steam generation speed and steam generation volume and power, and smoke generation as seen in "REMARKS". As mentioned, the combustion efficiency was clearly a matter of not only fuel efficiency but also freedom in military operations (i.e.,

[48] Dunbar [1854], pp. 53–54.

long-distance navigation in no-wind conditions and high-speed navigation during combat). It goes without saying that smoke generation were not investigated for the prevention of smoke nuisance but for military purposes (i.e., to ensure secrecy during steaming). Williams' smoke-control fire chamber, which was highly evaluated as a technology for smoke pollution control by the Select Committee on Smoke Prevention, was recognized for its military significance and tried for military purposes in the Royal Navy.

During trials in Newcastle, Williams' newly designed fire chamber received very high marks for smoke control and fuel efficiency. The trial of the new fire chamber was conducted using South Welsh coal, such as "Powell's Dufferyn" and "Blaengwarn Merthyr", and North England coal, such as "West Hartley Coal", "Buddle's West Hartley Coal", and "Lambton's Wallsend Coal". However, Williams' newly designed boiler fire chambers proved that bituminous coals from the northern countries could also be used to prevent smoke, and some of these coals could be burned more efficiently than South Welsh coals. It was also found that while South Welsh coal was relatively brittle, North England coal was more cohesive, and it was even stated that the latter was better suited for steamships when considering long-distance transportation, among others, since the problems of combustion efficiency and smoke were no longer issues.[49] It was also observed that the stoker's labor and ability to feed the coal into the fire chamber were no more demanding than when using South Welsh coal.[50]

The naval engineers were also guided by the association's engineers in visiting the mines where Williams' newly designed fire chamber, which they had refurbished, was installed and in use (the Cramlington West Hartley Collieries and the Bedlington Collieries), and in visiting the steam tug *Expert*. In both visits, Williams' fire chambers demonstrated near-perfect smoke control.[51]

Thus, the trial tests and inspection of Williams' newly designed fire chamber revealed that improved combustion efficiency and smoke control on steam vessels were possible, not only by relying on South Welsh coal but also by using a smoke-control fire chamber. It became clear that bituminous coal from the northern countries would be sufficient to meet the Royal Navy's requirements (high combustion efficiency and smoke control) if smoke-control fire chamber were used. However, matters subsequently took a turn for the worse, and the experiment's results almost lost their validity.

As noted, the experiments were led by the Northern England coal interest groups ("the Steam Collieries Association of the North of England" and "the Association for consuming the Smoke of Bituminous Coal when used in Tubular or other Marine Boilers"). As mentioned, South Welsh coal had come to be highly regarded as the fuel of choice for naval steamships as a result of various experiments up to that time,[52] and Cardiff was no longer considered to be in a position of monopoly in the supply of fuel to the Royal Navy. It would not be a stretch to speculate that the northern coal suppliers in Newcastle resisted this situation and set up this trial to promote the northern countries' bituminous coal to the

[49] HCPP, Copy of the report of Messrs. Miller and Taplin on the Evaporative Power and Economic Value of Hartley coal, p. 6.

[50] HCPP, Copy of the report of Messrs. Miller and Taplin on the Evaporative Power and Economic Value of Hartley coal, p. 4.

[51] HCPP, Copy of the report of Messrs. Miller and Taplin on the Evaporative Power and Economic Value of Hartley coal, p. 5.

[52] From the time of Playfair and De La Beche's studies on coal for naval steamships until shortly before Williams' fire chamber experiments at Newcastle, the naval arsenals at Woolwich and Portsmouth continued to conduct experiments comparing the burning efficiency and smoke production of South Welsh coal with those of coal from mainly the northern countries. The test results were generally positive for South Welsh coal (HCPP, Return of all coals tried at Woolwich and Portsmouth dockyards).

Navy.

However, a short time later, when the South Wales side learned of that experiment's results, their group naturally responded by inviting Taplan and W. Lynn, Assistant Inspector of Steam Equipment at Portsmouth Dockyard, to Cardiff to conduct a comparison experiment between South Welsh coals and North England coals under the leadership of "the South Wales Collieries Association". The South Welsh coals and the North England coals were burned in a standard fire chamber and in Williams' newly designed one, respectively. The results of the Cardiff experiment were the exact opposite of those obtained in Newcastle, shown to be inferior to South Welsh coals.[53]

Clearly, Northern England (Newcastle) and South Wales (Cardiff) each had a strong "spirit of rivalry actuating the parties concerned", as noted in Taplan's final report on the results of the experiment. Fearing that the rivalry might further escalate, the naval arsenal decided to take the side of South Wales in defusing the situation. For various reasons, the arsenal rejected the Newcastle experiment, which used the South Welsh coals that had been shipped from Woolwich Dockyard's coal yard and constituted a mixture of old and poor quality coals. The experimental boiler tried out at Newcastle had a larger heating space than the normal steamship boilers and were better in burning bituminous coal, and so on.[54]

As a result of the intensifying conflict of interest between the South Welsh coal suppliers and the Northern England coal suppliers, and as a result of its subsidence by the naval arsenal, the presence of Williams' newly designed fire chamber in the Navy was probably greatly reduced. After trial tests at Newcastle and Cardiff, Williams' smoke-control fire chamber could not be found in the main naval archives, to the best of the author's knowledge. It is believed that the combination of Williams' newly designed fire chamber and northern bituminous coal as a smoke-control measure adopted by the Royal Navy vessels never saw the light of day.

However, it was clear that smoke control continued to be recognized as an important military issue in the British steam navy in the mid-19th century, when it was still in its infancy. At that time, there was not much difference between land-use and ship-use smoke-control furnace or fire chamber. Under such circumstances, regardless of whether individual fire chambers were adopted or not, smoke-suppression fire chamber for the purpose of smoke pollution control could be converted into an important military technology relatively easily by changing the meaning and purpose of the fire chambers.

Conclusion: Transfer of smoke-control technology to Japan

The smoke-control technology for preventing smoke pollution (smoke-control fire chamber), which could be a military technology, was not necessarily British. However, since many of the steam boilers mainly used in early 20th-century Japan were of British types, such as Cornish, Lancashire, and Scotch, it is possible that in response to these types, many British fire chambers were introduced (and perhaps even imported) to Japan but without any special regulations.

In 1896, Iwato Kimura published *Shouen Gentan Kikanro* (Smoke Control and Saving Fuel Boiler Furnaces), which introduced smoke-preventing furnaces (newly designed ones

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53 HCPP, Copy of the report of Messrs. Miller and Taplin on the Evaporative Power and Economic Value of Hartley coal, pp. 12–15.

54 HCPP, Copy of the report of Messrs. Miller and Taplin on the Evaporative Power and Economic Value of Hartley coal, pp. 16–22.

and stable coal-feeding types) with design drawings, mainly from the United States, for the purpose of preventing smoke nuisance for consumer use. However, many of these American smoke-preventing furnace designs were highly similar to those developed in early- and mid-19th-century Britain.[55] Additionally, "Baien Boushi Kenkyukai" (the Society for Smoke Control Research), established in Osaka in 1911, investigated and reported the state of smoke control in the West and held exhibitions to introduce to the public the inventions and foreign products related to smoke prevention.[56]

The relation between the Imperial Japanese Navy and the above-mentioned smoke-control technology brought to Japan for the purpose of preventing smoke pollution is unclear. The Imperial Japanese Navy, which had access to South Welsh coal from the United Kingdom, probably had no interest in smoke-control fire chambers. However, if the Imperial Japanese Navy had faced a situation where South Welsh coal was unavailable before the interwar period, when the fuel shift from coal to oil was underway, it could not be ruled out that the smoke-suppression fire chamber would have been converted and utilized as an important military technology. In Britain in 1905, a document distributed at a meeting of Balfour's cabinet referred to the possibility of using oil as an alternative to South Welsh coal if it became unavailable. The document also mentioned the possibility of using more bituminous coal "with improved furnaces, &c., fittings" had been suggested.[57]

As discussed, smoke-control knowledge and technology used for the purpose of smoke pollution control, which at first glance may not seem to have much to do with the military but is considered peaceful knowledge and technology, may well be used for military purposes. On one hand, the smoke-control effect of the technology was sought by civilians to prevent smoke pollution. Another effect of the technology, namely improved combustion efficiency (fuel savings), was pursued to realize smoke pollution control that would not place too much burden on manufactures. On the other hand, in the Royal Navy, such technology was required to increase the freedom of military operations to enable long-distance navigation in no-wind conditions and high-speed navigation during combat, and the smoke-control effect was necessary to ensure secrecy during steaming. Knowledge and technology related to smoke control, which had been developed in the civilian sector for the prevention of smoke pollution, were utilized in the Navy by changing their purpose and meaning, thereby achieving a military semantic shift.

This conversion took place at the dawn of the British steam navy, when it was first confronted with a variety of problems—unique to the first steam warships—that had not been encountered in the case of sailing ships. It was also a time when steam engines and steam boilers for land use and for ship use still shared a certain degree of commonality. Of course, it was precisely because it was the dawn of naval steamships that knowledge and technology, developed for the purpose of preventing smoke pollution in the civilian world, were especially used for military purposes and that the fire chambers for land-based boilers were applied almost to the same extent as they were to naval steamships. In other words, it is undeniable that the cases discussed here were peculiar to the beginning of the development of certain military technologies. However, as the speed of technological progress has increased significantly at present compared to the mid-19th century, and the cycle of new military technologies and weapons has accelerated, more opportunities for civilian and consumer technologies are expected to be used at the early stages of development of many new military technologies and weapons. Air pollution (smoke

55 Kimura [1896].
56 Adachi [1933], p. 1468.
57 National Archives (CAB 1/6/1), The Supply of Welsh Steam Coal for the Navy, p. 4.

pollution) control technologies and environmental knowledge and technologies, such as those discussed in this paper, can be transferred relatively easily for international aid and exchange. It would be undesirable for technology that is transferred as an important tool for building peace to become a threat to that peace. The ambivalence of the technology to be transferred and the possibility of its military diversion seem to require more careful consideration than ever before.

Figure 1: Mid-19th-century Royal Navy wooden steamship (*HMS Driver*) (Winfield [2014], p. 321)

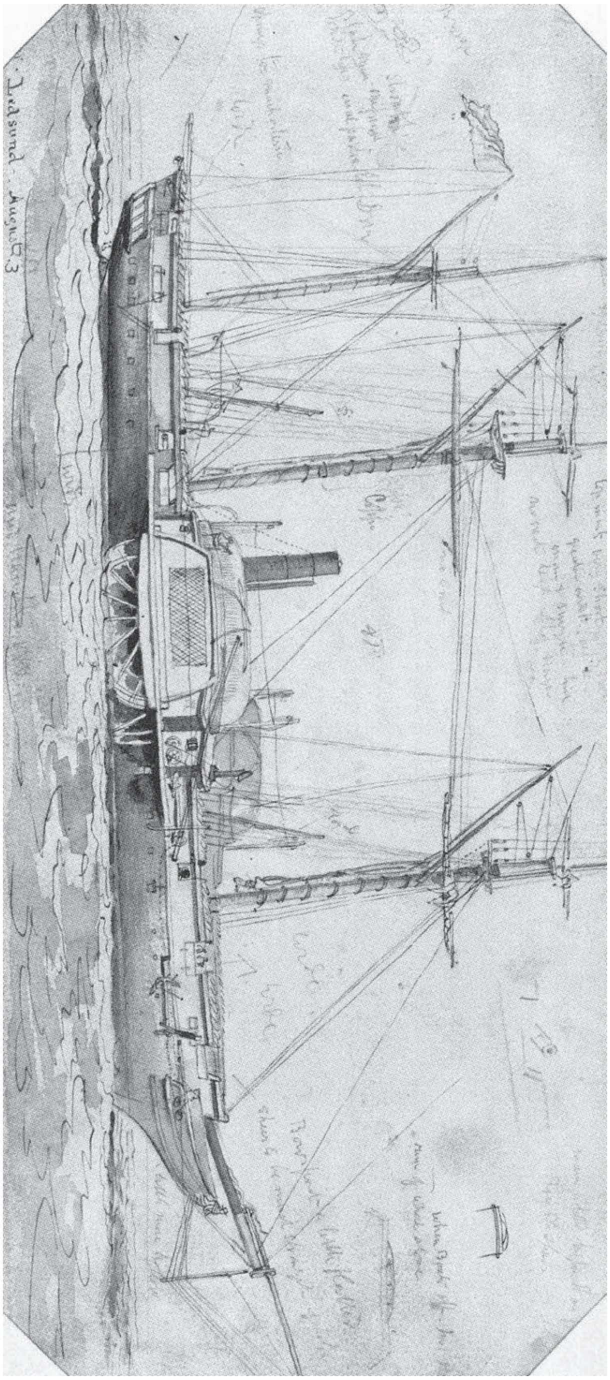

Figure 2: Charles W. Williams' smoke-control fire chamber

(House of Commons Parliamentary Papers, Copy of Messrs. Miller and Taplin's report on the Evaporative Power and Economic Value of Hartley coal, tracing B [from ProQuest online edition])

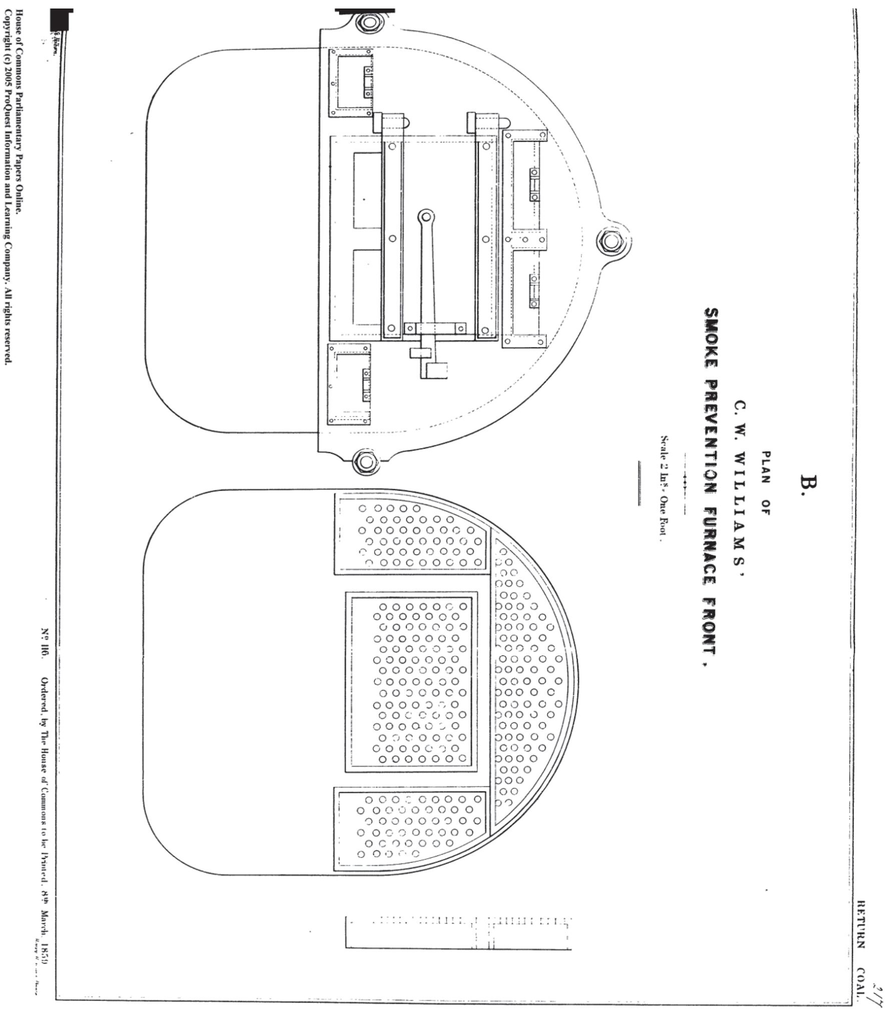

Figure 3: Experimental boiler used in the 1858 fire chamber and coal test by the naval arsenal

(House of Commons Parliamentary Papers, Copy of Messrs. Miller and Taplin's report on the Evaporative Power and Economic Value of Hartley coal, tracing A [from ProQuest online edition])

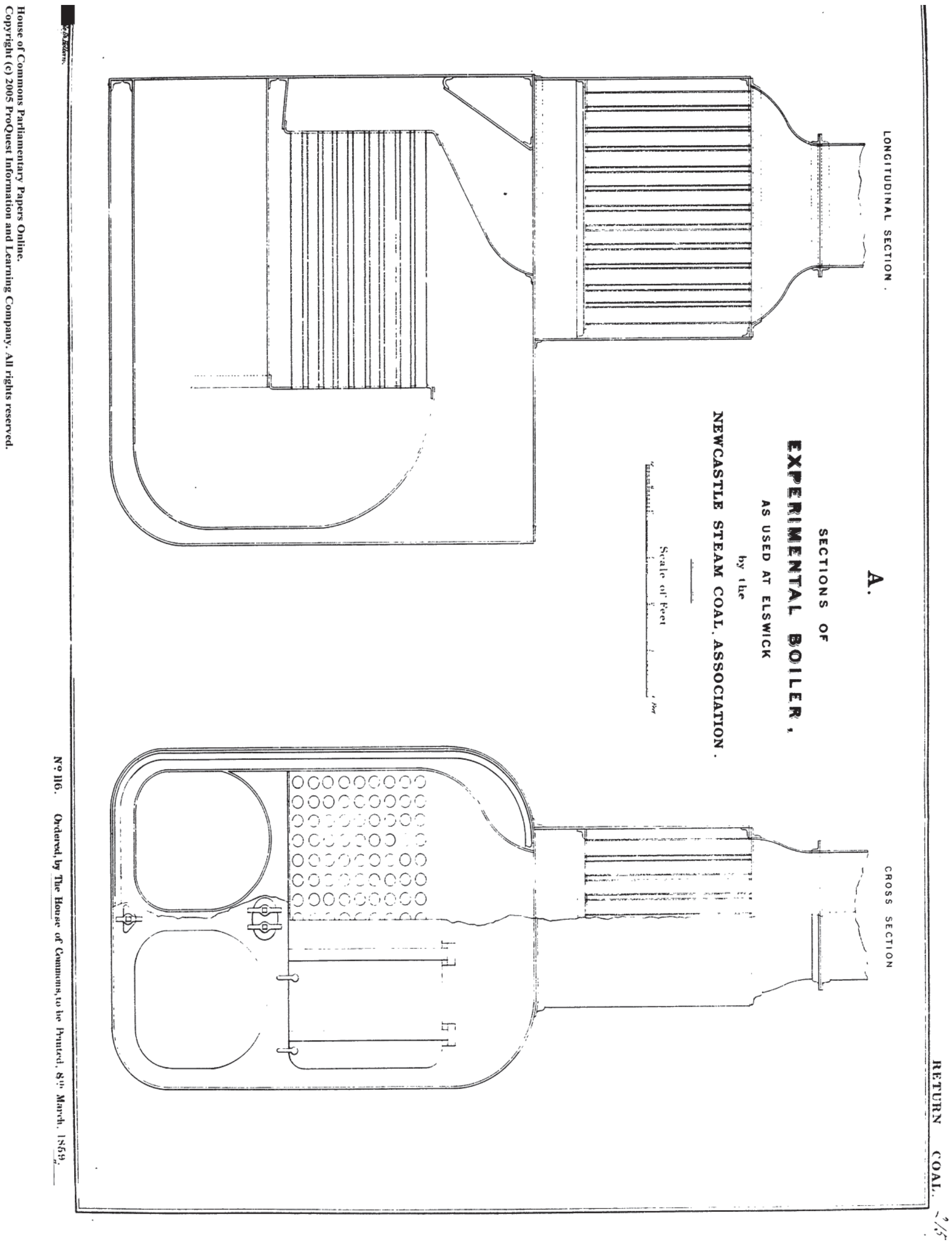

Table 1: Some results of the 1858 fire chamber and coal tests by the Navy arsenal

(House of Commons Parliamentary Papers, Copy of Messrs. Miller and Taplin's report on the Evaporative Power and Economic Value of Hartley coal, Table No. 1, p. 7 [From ProQuest online edition])

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OF HARTLEY AND WELSH STEAM COAL. 7

TABLES referred to in REPORT of the 19th August 1858, from Messrs. *Miller* and *Taplin*.

No. 1.—*Williams'* APPARATUS for CONSUMING SMOKE.

TABLE of Repetitional and Comparative Experiments with North Country Coal, and the Feed Water passing through the Heater.

Date of Experiment.	Description of Coal Experimented upon.	Area of Fire-grate.	Results calculated from the latent Heat of Steam, being 966°, as taken by Messrs. Armstrong, Longridge and Richardson, in their Reports to the Steam Collieries Association of the North of England.				Results calculated from the latent Heat of Steam, being 988°, as adopted by the Admiralty, in their Reports of Trials of Coals.		REMARKS.
			Economic Value on the Evaporation from 212°, by 1 lb. of Coal, in lbs. of Water.	Rate of Combustion, or Number of lbs. of Coals burnt per Square Foot of Fire-grate per Hour.	Rate of Evaporation from 60° per Square Foot of Fire-grate, in Cubic Feet, per Hour.	Total Evaporation from 60°, in Cubic Feet, per Hour.	Lbs. of Water evaporated by 1 lb. of Coal, calculated from constant Temperature of 100°.	Cubic Feet of Water evaporated per Hour, calculated from constant Temperature of 100°.	
1858:		*Feet.*	*Lbs.*	*Lbs.*	*Cubic Feet.*	*Lbs.*	*Lbs.*	*Cubic Feet.*	
26 June 3 July	West Hartley coal, sent from the colliery	22 22	10·97 11·47	28·51 25·97	4·18 4·02	92·00 88·43	9 82 10·25	95 38 91 64	During these experiments the air passages were open, and the smoke appeared to be wholly prevented. These are repetitional experiments.
19 July 20 July 22 July	Buddle's West Hartley coal, sent from Woolwich Dockyard	22 22 22	10·78 11·09 11·04	24·00 23 42 23·42	3·35 3·27 3·52	73·73 71·93 77·40	9·65 9·97 9·89	76·41 74·55 80·21	During these experiments the air passages were open, and the smoke appeared to be wholly prevented. These are comparative experiments.
26 July	Buddle's Hartley, direct from the colliery	22	10·29	27·49	3 79	83·33	9 21	86·36	This experiment was made to determine the evaporative values when this coal was obtained direct from the colliery. During this experiment the air passages were open, and no smoke visible from the chimney.
28 July	Hartley, small, direct from the colliery	22	10·78	17·31	2 51	55·20	9·65	57·21	This experiment was made to ascertain the evaporative value of the smaller particles into which North Country coal may be broken, from shipment or other causes. During this experiment, air passages were open and no smoke observable from the chimney.
29 July 30 July	West Hartley coal, direct from two other collieries in this district	22 22	11·42 11 08	23 04 26 05	3·39 3·73	74·74 81·98	10·21 9·92	77·46 84·95	These experiments were made to discover whether there were differences in the evaporative values of coal from the collieries of this district. During these experiments the air passages were open, and no smoke observable from the chimney.
2 August	West Hartley coal, direct from the colliery, and of the same description as in the two first experiments	18	11·66	24·89	3·78	68·09	10·44	70·57	During this experiment the air passages were open and the smoke completely prevented. This is a repetitional experiment.

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