# Appendix

**Discussions in the Imperial Diet regarding naval vessel incidents, January 1930–March 1940**

| *Date* | *Description* |
|---|---|
| 13 February 1931 | Questions about the cause of the collision between the cruiser *Abukuma* and *Kitakami*. (Shinya Uchida's questions were answered by the Minister of the Navy, Anbo, at the Lower House Budget Committee, the 59th Imperial Diet session.) |
| 2 March 1931 | Questions about the measures taken before and after the collision between the cruiser *Abukuma* and *Kitakami* during the large-scale manoeuvres in 1930 and the responsibility of the authorities. (Tanetada Tachibana's questions were answered by the Minister of the Navy, Anbo, at the House of Lords Budget Committee, the 59th Imperial Diet session.) |
| 17 March 1933 | Questions about the Minister of the Navy's view on the expenditure (12,000 yen) on repairs to the destroyer *Usugumo* and on the fact that the destroyer struck a well-known sunken rock. (Shinya Uchida's questions were answered by the Minister of the Navy, Osumi, at the Lower House Budget Committee, the 64th Imperial Diet session.) |
| 2 March 1935 | Request for information about the results of research on a scraping incident involving four destroyers, apparently on training duty in Ariake Bay, reported in newspapers. (Yoshitaro Takahashi's questions were answered by the Minister of the Navy, Osumi, at the Lower House Budget Committee, the 67th Imperial Diet session.) |
| 18 May 1936 | Request for information about the seriousness of the collision between submarines I-53 and I-63 and the amount of money drawn from the reserve for that. (Kanjiro Fukuda's questions were answered by the Accounting Bureau Director, Murakami, at the Lower House plenary session, the 69th Imperial Diet session.) |
| 18 May 1936 | Request for detailed information about the degree of damage to a destroyer due to violent waves in September 1935. (Kanjiro Fukuda's questions were answered by the Accounting Bureau Director, Murakami, at the Lower House plenary session, the 69th Imperial Diet session.) |
| 6 February 1939 | Brief explanation of the incident encountered by the submarine I-63. (The Minister of the Navy, Yonai, explained at the House of Lords plenary session, the 74th Imperial Diet session.) |

Continued

| *Date* | *Description* |
|---|---|
| 7 February 1939 | Brief explanation of the incident encountered by the submarine I-63. (The Minister of the Navy, Yonai, explained at the Lower House plenary session, the 74th Imperial Diet session.) |
| 25 February 1939 | Request for a brief explanation of the sinking of a submarine due to collision during manoeuvres. (Takeo Kikuchi's questions were answered by the Director of the Bureau of Military Affairs, Inoue, at the House of Lords Budget Committee, the 74th Imperial Diet session.) |
| 1 February 1940 | Brief report on the completion of the salvage of the sunk submarine I-63. (The Minister of the Navy, Yoshida, reported at the House of Lords plenary session, the 75th Imperial Diet session.) |

*Source*: Based on Kaigun Daijin Kanbo Rinji Chosa Ka (Temporary Research Section, the Minister of the Imperial Japanese Navy's Secretariat (ed.) *Teikoku Gikai Kaigun Kankei Giji Sokki Roku* (Minutes of Imperial Diet Sessions Regarding Navy-related Subjects), Bekkan 1, 2 (reprint, Tokyo: Hara Shobo, 1984).

## Materials of the Shibuya archives

| *Item* | *Number of materials* |
|---|---|
| Marine engineering | |
| Steam turbines (blades, rotors) | 85 |
| Steam turbines (domestic) | 237 |
| Steam turbines (foreign) | 133 |
| Reduction gearing | 108 |
| Condensers | 48 |
| Propellers/propulsion shafting | 145 |
| Boilers (general) | 228 |
| Boilers (velox boiler) | 19 |
| Boilers (feed water) | 56 |
| Boilers (automatic control) | 22 |
| Auxiliaries (general) | 151 |
| Auxiliaries (steering gear and others) | 50 |
| Auxiliaries (distilling plant) | 34 |
| Piping | 152 |
| Internal combustion engines | 392 |
| Gas turbines | 91 |
| *Rinkicho* failures | 45 |
| Materials | 206 |
| Fuel/lubricant | 47 |
| Submarines | 53 |
| Compendium & design of marine engines | 149 |
| Trial reports | 80 |
| Vibration/noise | 34 |

Continued

| *Item* | *Number of materials* |
|---|---|
| Bearing | 32 |
| General reports/bye-laws | 62 |
| Miscellaneous | 104 |
| Naval architecture | |
| Technical reports | 49 |
| Design | 47 |
| Hull structure | 125 |
| Materials/hull corrosion | 79 |
| Welding | 58 |
| Tanker/bulk carriers | 57 |
| Fishing vessels | 21 |
| Miscellaneous | 80 |
| Nuclear power | 170 |
| Weapons/weapons systems | |
| Guns | 7 |
| Gunpowder | 17 |
| Materials | 72 |
| Torpedoes | 7 |
| Ship electrical systems | 22 |
| Navigation systems | 5 |
| Warplanes | 55 |
| Miscellaneous, including manuscripts, memoranda, photographs, and others | 585 |
| Total | 4,219 |

*Source*: Shibuya Bunko Chosa Iinkai, Shibuya Bunko Mokuroku (Catalogue of the Shibuya archives), March 1995.

## A brief chronological table showing the main events of the *Rinkicho* failure

| | |
|---|---|
| 29 December 1937 | The failure occurred. |
| 19 January 1938 | The Minister of the Navy's Secretariat Military Secret No. 266 was issued, stating that it had been decided to establish the Special Examination Committee. |
| 3 February 1938 | The Minister of the Navy's Secretariat Secret Instruction No. 566 was issued, stating that it had been decided to examine the vibration of the main turbine blades and rotors installed in the naval vessels at the Hiro Naval Dockyard. |
| August 1938 | The Technical Headquarters Secret No. 15332 was issued specifying the methods of static and dynamic vibration tests on turbine blades and rotors. |
| 2 November 1938 | Report from the Committee (Top Secret No. 35) summarizing the 53 subcommittee meetings and 13 general meetings held up to then. |

Continued

| | |
|---|---|
| 1 April 1939 | The Minister of the Navy's Secretariat Secret Instruction No. 1973 was issued, stating that it had been decided to select a representative naval vessel from the existing naval vessels, excluding the *Asashio*-class destroyers for which remedy had already been implemented, and to conduct long-run load tests according to the remedy implementation schedule suggested by the Special Examination Committee's report. |
| 12 February 1940 | The Minister of the Navy's Secretariat Secret Instruction No. 1122 was issued, stating that it had been decided to begin turbine rotor load tests at the Engine Experiment Department, the Maizuru Naval Dockyard in April 1940. |
| 6 May 1940 | The Minister of the Navy's Secretariat Secret Instruction No. 3185 was issued to postpone the modification to the main turbines of the existing naval vessels. |
| 20 June 1941 | The Minister of the Navy's Secretariat Secret Instruction No. 5389 was issued, stating that it had been decided to postpone the completion of turbine rotor load tests to March 1943, postpone the modification to the main turbines of the naval vessels, and make the final decision by consulting the results of on land tests by the end of June 1943. |
| 8 December 1941 | War with the US and Britain declared. |

*Source*: Based on Shun Murata, '*Asashio* Gata Shu Tabin no Jiko' (An accident of the main turbines of the *Asashio*-class), manuscript, n.d.

# Notes

## 1 Introduction: Problems and Approaches

1. Social change here means the structural change of patterns linking men, artefacts, and nature, extending over a long period rather than the temporary shift of social phenomena.
2. See Eitaro Noro, *Nihon Shihonshugi Hattatsu Shi* (A history of the development of capitalism in Japan) (Tokyo: Iwanami Shoten, 1954), p. 85; Robert U. Ayres, *The Next Industrial Revolution: Reviving Industry through Innovation* (Cambridge, Mass.: Ballinger, 1984), pp. 10–125, *et al.*
3. See G. Meyer-Thurow, 'The industrialization of innovation: a case study from the German chemical industry', *Isis*, vol. 73, no. 268 (1982), pp. 363–81; George Wise, 'Ionist in industry: Physical chemistry at G. E., 1900–1915', *Isis*, vol. 74, no. 271 (1983), pp. 7–21; L. S. Reich, 'Industrial research and the pursuit of corporate security: the early years of Bell labs', *Business History Review*, vol. 54, no. 4 (1980), pp. 504–29, and others. For cases in the 1920s, see Yasu Furukawa, *Inventing Polymer Science: Staudinger, Carothers and the Emergence of Macromolecular Chemistry* (Philadelphia: Pennsylvania University Press, 1998), and others.
4. In either case, according to Anthony Giddens, a stereotypical generalization such as: 'it is the technological … level of development of a society that "in the last resort" determines the processes of change which affect it' seems to have been assumed (Anthony Giddens, *The Class Structure of the Advanced Societies*, London, Hutchinson, 1973, p. 265). Based on a survey of literature on the sociology of industrial and post-industrial societies, Richard Badham put the assumption in a different manner: 'The great transformation had occurred and while there could be no turning back it was also impossible to bring about a radical social reconstruction within or beyond the new social order. The development of science, frequently associated with this transformation … revealed the inevitability of this transition and the necessary constraints that it imposed on human action.' (R. Badham, 'The sociology of industrial and post-industrial societies', *Current Sociology*, vol. 32, no. 1 (1984), p. 22.) For a classical work giving the foundation of the continuous industrialization models based on the assumption, see C. Kerr, J. T. Dunlop, F. H. Harbison and C. A. Myers, *Industrialism and Industrial Man* (Cambridge, Mass.: Harvard University Press, 1960). For another classical proponent of the discontinuous development stage model based on a similar assumption, see Karl Marx, *Das Kapital: Kritik der politischen Ökonomie*, bd. 1, buch 1 (Hamburg: Otto Meissner, 1867).
5. Farbenfabriken Bayer AG, *Fünfzig Jahre Bayer Arzneimittel, 1888–1938* (Leverkusen, 1938); John D. Scott, *Siemens Brothers, 1858–1958: An Essay in the History of Industry* (London: Weidenfeld & Nicolson, 1958); G. Wise, 'A new role for professional scientists in industry: industrial research at General Electric, 1900–1916', *Technology and Culture*, vol. 21, no. 3 (1980), pp. 408–29; idem., 'Ionist in industry'; Francis E. Leupp, *George Westinghouse: His Life and Achievements* (Boston: Little Brown, 1918), and others.
6. David S. Landes, *Prometheus Unbound* (Cambridge: Cambridge Univ. Press, 1969), p. 235. Additions in brackets are mine.

7. In general, whether we can expect rich sociological implications is completely distinct from whether a case taken up is on the leading edge of advance of industrial societies. For a comprehensive guide for understanding and developing this point, see Robert Fox (ed.) *Technological Change: Methods and Themes in the History of Technology* (Amsterdam: Harwood, 1996).
8. One of the first to attack the amateur tradition was Charles Babbage, a mathematician known as an inventor of the computer for his work on difference and analytical engines. As early as 1830, he severely criticized the Royal Society, pointing out that more than 40 per cent of the Fellows of the society were amateur gentlemen who had never contributed to the *Philosophical Transactions*, the society's journal. See C. Babbage, *Reflections on the Decline of Science in England* (London: B. Fellowes, 1830), pp. 226–8, appendix no. 3. Just ten years later, William Whewell, a professor of moral philosophy at Cambridge, introduced the new word 'scientist' instead of the traditional word 'natural philosopher'. See W. Whewell, *The Philosophy of the Inductive Sciences* (London: John W. Parker, 1840), vol. I, p. cxiii. In 1851, the Sixth Census of England and Wales introduced a new category, 'scientific person', a reflection of changing occupational titles. See Census of England and Wales for the Year 1861, vol. III (London, 1863), p. 32. As for professional engineers, the so-called 'technical education movement' became widespread in the second half of the nineteenth century, which led to the Royal Commission on the subject. See *Second Report of the Royal Commissioners on Technical Instruction* (London, 1884).
9. Although there are differences between England and Scotland in terms of engineering education and its relationship to shipbuilding, this book does not go into them.
10. T. Goode, 'Nihon ni okeru zosengyo' (The shipbuilding industry in Japan), *Kogyo*, no. 14 (1909), pp. 28–32 (abridged translation into Japanese). According to an industrial census-based index showing the rate of increase in industrial output in terms of currency value from 1909 to 1914, the machinery industry came first (257.8) and the metal industry next (222.4). Within the machinery industry, 'the largest was shipbuilding'. See Tsusho Sangyo Daijin Kanbo Chosa Tokeibu, *Kogyo Tokei 50 Nen Shi* (A history of the Census of Manufactures 1909–1958) (Tokyo: Ryukei Shosha, 1961), Kaisetsu Hen, pp. 36–7.
11. Edgar C. Smith, *A Short History of Naval and Marine Engineering* (Cambridge: Cambridge Univ. Press, 1938), p. 360.
12. *Second Report of the Royal Commissioners on Technical Instruction* (London, 1884), vol. I, p. 507.
13. *Final Report on the First Census of Production of the United Kingdom, 1907*, pt 2 (London, 1913), pp. 125–38, pp. 542–93, pp. 845–63.
14. As for the relationship between Japanese and Western shipbuilding, see H. Adachi, *Iyo no Fune: Yoshiki Sen Donyu to Sakoku Taisei* (The introduction of Western ships and the closed-door policy of Japan) (Tokyo: Heibonsha, 1995).
15. 'Kogaku soshi kokan no shushi' (Editorial for *Kogaku Soshi*), *Kogaku Soshi*, vol. 1 (1881), p. 1.
16. Rinzaburo Shida, 'Kogyo no shinpo wa riron to jikken tono shinwa ni yoru' (The marriage of theory and experiment produces industrial progress), *Kogaku Soshi*, vol. 6, pt 67 (1887), pp. 425–50.
17. Ibid., p. 441.
18. Ibid., p. 449.
19. No Shomu Sho (ed.) 'Kogyo Iken' (Opinions on industrialization), vol. 11 (1884), in Hyoe Ouchi and Takao Tsuchiya (eds), *Meiji Zenki Zaisei Keizai Shiryo Shusei* (Compilation of documents on finance and economy in the early Meiji period), vol. 18, pt 2 (Tokyo: Meiji Bunken Shiryo Kanko Kai, 1964), p. 436.

20. As for how the plan was eventually implemented only partially and unsatisfactorily, see Chikayoshi Kamatani, *Gijutsu Taikoku Hyakunen no Kei: Nippon no Kindaika to Kokuritsu Kenkyu Kikan* (The road to techno-nationalism: Japanese modernization and national research institutes from the Meiji era) (Tokyo: Heibonsha, 1988).
21. The government also utilized students dispatched overseas by the Ministry of Education, which forms a separate topic, since their purposes were broadly prescribed as 'studying art and advanced learning', and they therefore had less direct relation to the creation of the institutional framework of industrialization in the ongoing scientific and technological revolution. See *Annual Report of the Ministry of Education*, no. 20 (1892), no. 34 (1906), and others (the quotation is ibid., no. 34 (1906), p. 17).
22. Calculated from *Nippon Teikoku Tokei Nenkan* (Statistical yearbook of the Japanese empire) (Tokyo: Tokyo Tokei Kyokai), no. 2 (1883), no. 18 (1899). When we extend the period to 1869–1900 and include the employees coming from the British empire, the figure amounts to 1034 in total. See H. J. Jones, 'The Griffith thesis and Meiji policy toward hired foreigners', in Ardath W. Burks (ed.) *The Modernizers: Overseas Students, Foreign Employees and Meiji Japan* (Boulder, Colo.: Westview, 1985), pp. 219–53. For a study focusing on the personal histories of foreign employees, see Tadashi Shimada, Minoru Ishizuki, Noboru Umeso, Tadashi Kaneko, Yukihiko Motoyama, Masao Watanabe (eds) *The Yatoi: Oyatoi Gaikokujin no Sogoteki Kenkyu* (A study of foreign employees) (Tokyo: Shibunkaku Shuppan, 1987).
23. James A. Ewing, 'Preliminary Report on Trials of the Steamer *Turbinia*', 24 April 1897, Tyne and Wear Archives Service (Newcastle-upon-Tyne).
24. The major governmental departments involved in manufacturing industries, except for the Ministry of Communications (established in 1885), inherited almost all their functions from the departments of the old Cabinet (Dajokan) existing before 1885: the Ministry of Finance (Okura Sho, 1869), Ministry of Foreign Affairs (Gaimu Sho, 1869), Ministry of Engineering (Kobu Sho, 1870), Ministry of Education (Monbu Sho,1871), Ministry of Justice (Homu Sho, 1871), Ministry of Agriculture and Commerce (1871), and Ministry of Internal Affairs (Naimu Sho, 1873) had all started their work before 1885.
25. Okura Sho (ed.), 'Kobu Sho Enkaku Hokoku' (The origin of the Ministry of Engineering), 1887, in Ouchi and Tsuchiya, *Meiji Zenki Zaisei Keizai Shiryo Shusei*, pp. 5–6, p. 150. Soon after Morell's arrival in Japan, he became ill. The Meiji government did everything for his recovery, spending an extraordinary amount on medical fees (5000 yen), but his illness proved fatal (ibid., p. 150).
26. Estimated from ibid., table 1 (pp. 469–70); Toshio Furushima, *Shihonsei Seisan no Hatten to Jinushisei* (The development of capitalism and the landlord system in Japan) (Tokyo: Ochanomizushobo, 1963), p. 267. The total expenditure of the ministry can be arrived at by summing overheads (*Eigyo hi*) and industrial expenses (*Kogyo hi*).
27. Kyu Kobu Daigakko Shiryo Hensan Kai (ed.) *Kyu Kobu Daigakko Shiryo* (Documents and materials of the Engineering College) (Tokyo: Toranomon Kai, 1931), p. 129. This passage is taken from a speech from the throne at the inauguration ceremony of the Engineering College held on 11 April 1878.
28. The above-mentioned E. Morell also initially advised setting up the forerunner of the college (Kogaku Ryo). For the services of Henry Dyer, see Nobuhiro Miyoshi, *Dyer no Nippon* (Dyer and Japan) (Tokyo: Fukumura Shuppan, 1989), and others. For Dyer's own observations on contemporary Japanese society, see H. Dyer, *Dai Nippon: The Britain of the East, A Study in National Evolution* (London: Blackie, 1904).

29. The passage is taken from a speech by Dyer, in Nobuhiro Miyoshi, *Nihon Kogyo Kyoiku Seiritsu Shi no Kenkyu: Kindai Nihon no Kogyoka to Kyoiku* (A history of industrial education in modern Japan) (Tokyo: Kazama Shobo, 1977), p. 279.
30. Teiyukai, *Kobu Daigakko Mukashibanashi* (Reminiscences of the Engineering College), Teiyukai Brochure, no. 1 (1926), p. 15.
31. 'Engineering education in Japan', *Nature*,17 May 1877, pp. 44–5.
32. Ayahiko Ishibashi, Reminiscence, pt 2, 'Ayrton sensei no oshiekata' (How Professor Ayrton taught), in Kyu Kobu Daigakko Shiryo Hensan Kai (ed.) *Kyu Kobu Daigakko Shiryo*, appendix. The author was a first-class graduate (1879) of the Engineering College. 'Professor Ayrton' was William Edward Ayrton who taught physics and electrical engineering at the Engineering College from 1873 to 1878 and determined the gravity at Tokyo during his stay in Japan.
33. Kyu Kobu Daigakko Shiryo Hensan Kai, *Kg Kobu Daigakko Shiryo*, pp. 133–4. The degree of bachelor later came to be given to second-class graduates as well. Ibid., p. 180. No certificate of graduation at all was given to third-class graduates.
34. Teiyukai, *Kobu Daigakko Mukashibanashi* (Reminiscences of the Engineering College), p. 35.
35. See Okura Sho, 'Kobu Sho Enkaku Hokoku', pp. 405–8.
36. Shida was the founding father of the Electrical Engineering Society in Japan mentioned below, whose life has attracted historians' interest. For a standard biography, see Fumio Shida, 'Shida Rinzaburo, Tomiko Kinenroku' (Memories of Rinzaburo and Tomiko Shida) (Tokyo, for private distribution, 1927).
37. This *samurai* background of modernizers of Meiji Japan has provided one of the popular subjects in the field of Japanese industrialization. For a general description based on aggregate data, see Everett E. Hagen, *On the Theory of Social Change: How Economic Growth Begins* (London: Tavistock, 1962), pp. 349–52, ch. 14, appendix table 14.1. For scientists and engineers, see W. H. Brock, 'The Japanese connexion: engineering in Tokyo, London, and Glasgow at the end of the nineteenth century', *British Journal for the History of Science*, vol. 14, no.48 (1981), pp. 227–3; Eikoh Shimao, 'Some aspects of Japanese science, 1868–1945', *Annals of Science*, vol. 46, no. 1 (1989), pp. 69–91; Shigeru Nakayama, *Science, Technology and Society in Postwar Japan* (London: Kegan Paul, 1991), p. 103, n. 4.
38. For the index of industrial production increase in value terms on a monetary basis, see Somucho Tokeikyoku (ed.) *Nihon Choki Tokei Soran* (Long-term statistical trends of Japan), vol. 2 (Tokyo: Nihon Tokei Kyokai, 1988), p. 434. For the rising level of education measured in terms of the percentage of children attending school, see Monbusho Chosakyoku (ed.) *Nihon no Seicho to Kyoiku: Kyoiku no Tenkai to Keizai no Hattatsu* (Growth and education in Japan: educational and economic developments) (Tokyo: Teikoku Chiho Gyosei Gakkai, 1965), appendix 3, materials, pp. 180–1. The urban population rose from 7.9 per cent of the nation in 1898 to 11.6 per cent in 1925. The urban population is estimated by summing the population of the eight largest cities in Japan (Tokyo, Yokohama, Nagoya, Kyoto, Osaka, Kobe, Hiroshima, Fukuoka), based on Somucho Tokeikyoku data, *op.cit.*, vol. 1 (1987), pp. 66–7, p. 168.
39. Although these points do not fulfil strict one-to-one correspondence to (1) specialization and (2) vocationalization, they are close enough to indicate a general trend. According to sociological usage, a professional society might suggest an authoritative group somewhere between *Gemeinschaft* and *Gesellschaft*.
40. *Denki Gakkai 50 Nen Shi* (Half a century of the Electrical Engineering Society) (Tokyo: Denki Gakkai, 1938), p. 4.

41. 'Nihon Kogaku Kai hyakushunen o mukaete' (Commemorating the centenary of the Engineering Society of Japan), in Nihon Kogaku Kai (ed.) *Kogaku Soshi/Kogaku Kaishi So Sakuin* (A general catalogue of the Engineering Journal) (Tokyo: Yushodo, 1983).
42. This is also confirmed by the fact that the Ministry of Engineering and the Engineering College, having fulfilled their mission of providing an infrastructure for industrialization and fostering human resources, were both abolished in 1885. Specialization, by definition, presupposed these initial investments in human resources and the infrastructure that backed them up.
43. Contemporary engineering-related professional societies in the field of chemistry could also provide a model relevant to the scientific and technological revolution. However, since the Chemical Society (Kagaku Kai) and the Society for Industrial Chemistry (Kogyo Kagaku Kai) were set up independently within this same field (see Table 1.1), it is difficult to employ the field as another model for estimating the degree of vocationalization on an equal footing. The separation of the two societies was so serious that even the president of the Chemical Society, Joji Sakurai, deplored the situation at its fiftieth anniversary (it was not until the post-war period that the situation changed). See Hiroshi Ishiyama, 'Nihon no gaku kyokai' (Professional societies in Japan), *Gijutsu to Keizai*, no. 204 (1984), pp. 26–38. For a standard work on the process of development of Japanese industrial chemistry up to the 1910s, see Chikayoshi Kamatani, *Nihon Kindai Kagaku Kogyo no Seiritsu* (The evolution of modern industrial chemistry in Japan) (Tokyo: Asakura Shoten, 1989).
44. That is to say, under the first strategy of the Meiji government it was from Britain that the greatest number of foreign employees were introduced, but the second strategy resulted in a different process of professionalization from that in Britain. Whether original achievements were seen in the content of professional science and technology in contemporary Japan is a separate question, which will be discussed in detail in later chapters.
45. In a sense this assumption can be another face of technological determinism. For technological determinism, cf. Merritt Roe Smith and Leo Marx (eds), *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Mass.: MIT Press, 1994). As for the economic model, the following point has already been noted: 'technology transfer almost always occurs because of economic motives, but economic models do not fully explain the process' (David J. Jeremy (ed.) *Technology Transfer and Business Enterprise* (Aldershot: Edward Elgar, 1994), p. xxiii). Although several sociologists have studied the diffusion of technology, they have tended to deal with it by constructing a rather abstract typology. See, for example, Everett Rogers and Floyd Shoemaker, *Communication of Innovation: A Cross-Cultural Approach* (New York: Free Press, 1971), excerpted in ibid., pp. 52–97. For another sort of historical study on technology transfer with sociological implications, cf. Svante Lindqvist, *Technology on Trial: The Introduction of Steam Power Technology into Sweden, 1715–1736* (Stockholm: Almqvist & Wiksell, 1984); Tatsuya Kobayashi, *Gijutsu Iten: Rekishi karano Kosatsu* (Technology transfer: observations on history) (Tokyo: Bunshindo, 1981), ch. 2.
46. Kurt Lewin, 'Forces behind food habits and methods of change', *Bulletin of the National Research Council*, vol. 108 (1943), p. 65.
47. Diana Crane, 'The gatekeepers of science: some factors affecting the selection of articles for scientific journals', *American Sociologist*, vol. 2 (1967), pp. 195–201. The usage was then enlarged by Harriet Zuckerman and Robert Merton to include

the role of regulating scientific manpower and allocating resources for scientific research. See H. Zuckerman and R. K. Merton, 'Age, aging, and age structure in science', in Matilda White Riley, Marilyn Johnson, and Anne Foner (eds) *A Sociology of Age Stratification*, vol. 3 (New York: Russel Sage Foundation, 1972), reprinted in Robert K. Merton, *The Sociology of Science: Theoretical and Empirical Investigations* (Chicago: University of Chicago Press, 1973), pp. 497–559.

48. Thomas J. Allen, *Managing the Flow of Technology* (Cambridge, Mass.: MIT Press, 1977), pp. 141–63.
49. For one direction of development, see, for example, Thomas Allen, Michael L. Tushman and Denis M. Lee, 'Technology transfer as a function of position in the spectrum from research through development to technical service', *Academy of Management Journal*, vol. 22, no. 4 (1979), pp. 694–708; for another way, see, for example, Michael L. Tushman and Ralf Katz, 'External communication and project performance: an investigation into the role of gatekeepers', *Management Science*, vol. 26, no. 11 (1980), pp. 1071–85. For an effort to identify gatekeepers, see Jane E. Klobas and Tanya McGill, 'Identification of technological gatekeepers in the information technology profession', *Journal of the American Society for Information Science*, vol. 46, no. 8 (1995), pp. 581–9.
50. On the genealogy of the term with particular reference to this point, see Stuart Macdonald and Christine Williams, 'Beyond the boundary: an information perspective on the role of the gatekeeper in the organization', *Journal of Product Innovation Management*, vol. 10 (1993), pp. 417–27.
51. What is striking about the college is that it placed great emphasis on scientific subjects (for example, mathematics, physics, chemistry, applied dynamics) relevant to the ongoing scientific and technological revolution in shipbuilding, and the recruitment of suitable professors to teach the subjects. See *Report of the Committee Appointed to Inquire into the Establishment of the Royal Naval College, Greenwich* (London, 1877), appendix no. 1. As for the background to the establishment of the college, see W. John, 'On the Royal Naval College and the merchant marine', *Transactions of the Institution of Naval Architects* (abbreviated to *TINA* hereafter), vol. 19 (1878), pp. 120–36.
52. Kenichi Tominaga, *Nihon no Kindaika to Shakai Hendo* (Japanese modernization and social change) (Tokyo: Kodansha, 1990), p. 3. Apart from the outstanding place the author has as a researcher in sociological theories in Japan, one of the main reasons for this focus on the author is his broad international prominence as a proponent of this view of Japan's industrialization process, which dates back to the early 1970s. See, for example, *idem*, 'Développement et changement social au Japon: une analyse parsonienne', *Sociologie du Travail*, no. 3 (1973), pp. 269–92. As to the relationship between history and sociology, see, for example, Phillip Abrams, *Historical Sociology* (Ithaca: Cornell University Press, 1983).
53. Tominaga, *Nihon no Kindaika*, p. 144.
54. For an example in economic history, see Hisao Otsuka, 'Kindaika to sangyoka no rekishiteki kanren ni tsuite: Tokuni hikaku keizaishi no shikaku kara' (The historical relation between modernization and industrialization, from the viewpoint of comparative economic history), in *Otsuka Hisao Chosaku Shu* (Collected works of Hisao Otsuka), vol. 4 (Tokyo: Iwanamishoten, 1969), pp. 273–92 (first appeared in *Tokyo Daigaku Keizaigaku Ronshu*, vol. 32, no. 1 (1966), pp. 1–10). For an example in politics, see Masao Maruyama, 'Nihon ni okeru jiyu ishiki no keisei to tokushitsu' (The formation and characteristics of a sense of liberty in Japan), in *idem.*, *Senchu to Sengo no Aida: 1936–1957* (During the war and after: 1936–1957)

(Tokyo: Misuzushobo, 1976), pp. 297–306 (first appeared in *Teikoku Daigaku Shinbun*, 21 August 1947). As an example in the history of science, see Kinnosuke Ogura, 'Ware kagakusha taru o hazu' (I am ashamed of being a scientist), in *Ogura Kinnosuke Chosaku Shu* (Collected works of Kinnosuke Ogura), vol. 7 (Tokyo: Keisoshobo, 1974), pp. 124–44 (first appeared in *Kaizo*, January 1953).

55. Giddens, *The Class Structure of the Advanced Societies*, p. 165. Although we can certainly find secondary sources mentioned in this context in references and notes, virtually no evidence seems to be adduced to prove the point straightforwardly. Compared with the 'indigenous' British industrialization, Marius B. Jansen and Lawrence Stone also state (concerning Japanese industrialization): 'A ruthlessly modernizing section of the elite seized power in a highly authoritarian society, and deliberately discarded everything which did not contribute to strengthening the resources of the state.' M. B. Jansen and L. Stone, 'Education and modernization in Japan and England', *Comparative Studies in Society and History*, vol. 9, no. 2 (1967), pp. 208–32. In appraising prior studies on Japanese fascism, George Macklin Wilson refers to Germany and Japan 'where rapid modernization spurred on by the power of the state had brought a relatively high level of development'. G. M. Wilson, 'A new look at the problem of "Japanese Fascism" ', *Comparative Studies in Society and History*, vol. 10, no. 4 (1968), pp. 401–12.
56. See Tetsu Hiroshige, *Kagaku no Shakaishi: Kindai Nihon no Kagaku Taisei* (The social history of science: institutionalization of science in modern Japan) (Tokyo: Chuokoronsha, 1973); Chikayoshi Kamatani, *Gijutsu Taikoku Hyakunen no Kei: Nippon no Kindaika to Kokuritsu Kenkyu Kikan* (The road to techno-nationalism: Japanese modernization and national research institutes from the Meiji era) (Tokyo: Heibonsha, 1988).
57. Kamatani, *Gijutsu Taikoku Hyakunen no Kei*, p. 80.
58. This becomes still more striking if it is remembered that the same author once pointed out the pitfalls of understanding Japanese industrialization as a process of co-opting science and technology to state control. See C. Kamatani, 'Kigyo o chushin toshita kenkyu taisei no suii: Sono rekishiteki hatten no tokucho' (Trends in the institutionalization of research with particular reference to company R&D), in T. Hiroshige (ed.) *Nihon Shihonshugi to Kagaku Gijutsu* (Capitalism, science and technology in Japan) (Tokyo: Sanichi Shobo, 1962), pp. 92–153.
59. As for the detailed examination of the point developed here, see M. Matsumoto, 'Review: The road to techno-nationalism: Japanese modernization and national research institutes from the Meiji era', *Historia Scientiarum*, no. 38 (1989), pp. 75–80.
60. For 'the big picture' in the history of science and technology, see 'A special issue: the big picture', *British Journal for the History of Science*, vol. 26, no. 91 (1993). What is means by the big picture in some contexts seems to have a function similar to the stereotypes this chapter refers to. And James A. Secord, a guest editor, is certainly right in saying 'big picture should not be confused with textbooks' (ibid., p. 388.) It seems to me that there is one important point not given due emphasis: more than simply broadening topics by importing something new from other fields, or providing episodic accounts based on chronology, what is needed is to produce consistent frameworks to pose significant questions and answer them.

## 2 The Technology Gatekeepers: The Role of the Navy and Mitsubishi in the Ship Revolution

1. The phrase 'transfer of a professionalized science and technology' is used here to refer to the transfer of innovation during a limited historical period, from the end

of the nineteenth century to the present. It emphasizes that what is transferred is the results of the scientific and technological revolution. Previous studies on pre-war technology transfer to Japan include the following references: Tatsuya Kobayashi, *Gijutsu Iten* (Observations based on the history of technology transfer: the US and Japan) (Tokyo: Bunshindo, 1981); Tetsuro Nakaoka, 'On technological leaps of Japan as a developing country: 1900–1940', *Osaka City University Economic Review*, vol. 22 (1987), pp. 1–25; Hoshimi Uchida, 'Gijutsu iten' (Technology transfer), in S. Nishikawa and T. Abe, *Nihon Keizaishi 4 Sangyoka no Jidai* (History of Japan's economy IV: the age of industrialization), vol. 1 (Tokyo: Iwanami Shoten, 1990), pp. 256–302; Ian Inkster, *Science and Technology in History: An Approach to Industrial Development* (London: Macmillan, 1991), esp. pp. 184–204. Regrettably, there is little corroborative study of Japan's science and technology transfer by sociologists. As one of the few exceptions, see Takeshi Hayashi, *Japanese Experience in Technology: From Transfer to Self-Reliance* (Tokyo: United Nations University Press, 1990).

2. Tetsu Hiroshige, *Kagaku no Shakaishi* (The social history of science) (Tokyo: Chuokoronsha, 1973), pp. 80–1. Hiroshige was the first scholar to describe the social history of modern Japanese science and technology within the global trend to the professionalization of science and technology, who went beyond the dichotomy of superiority or inferiority latent within the Japanese cultural mentality with respect to the West. 'Cultural mentality' is used to refer to the concepts, customs and beliefs that govern the life and thought of a particular society. This concept dates back to Pitirim A. Sorokin, an American sociologist in the 1930s and 1940s. The effectiveness of this concept was criticized by his disciple Robert K. Merton, who wrote that 'quite apart from the differences of intellectual outlook of diverse classes and groups … Sorokin's approach is primarily suited for an overall characterization of cultures, not for analyzing connections between varied existential conditions and thought within a society.' As concerns the original usage of the term by Sorokin, reference can be made to P. A. Sorokin, *Social and Cultural Dynamics* (New York: American, 1937), vol. 1, pp. 72–3. For Merton's criticism, see R. K. Merton, *Social Theory and Social Structure: Towards the Codification of Theory and Research* (New York: Free Press, 1949), p. 467. For the relation between culture and technology in the US, see Bruce Sinclair, *New Perspectives on Technology and American Culture* (Philadelphia: American Philosophical Society, 1986).
3. 'Gap' here indicates the difference in the potential of science and technology between the two countries determined by the quality and quantity of the knowledge of the research front of a specific field of science and technology.
4. See also Chapter 5.
5. The approach adopted here analyses the problem from the viewpoint of the agents involved, without relying on the notion of historical accident. Whether approached from an individual decision or aggregate behaviour basis, or from the characteristics of a group as a collective entity (emergent property), an explanation based on historical accident without allowing for human intervention tells us very little sociologically.
6. John I. Thornycroft, 'On the resistance opposed by water to the motion of vessels of various forms, and the way in which this varies with the velocity', *TINA*, vol. 10 (1869), pp. 144–54.
7. Discussion appended to ibid., pp. 150–1. Interpolations are mine.
8. Discussion appended to ibid., p. 152.
9. Ibid., p. 144.

10. The descriptions are based on C. W. Merrifield, ‘Experiments recently proposed on the resistance of ships’, *TINA*, vol. 11 (1870), pp. 80–93.
11. Reports of the Annual Meeting of the British Association for the Advancement of Science held at York in 1831, p. 10, quoted in A. Derek Orange, ‘The beginning of the British Association: 1831–1851’, in Roy MacLeod and Peter Collins (eds) *The Parliament of Science: The British Association for the Advancement of Science, 1831–1981* (Northwood: Science Review, 1981), pp. 43–64.
12. Charles Babbage, *Reflections on the Decline of Science in England, and on Some of Its Causes* (London: B. Fellowes, 1830), p. 152.
13. See O. J. R. Howarth, *The British Association for the Advancement of Science: A Retrospect 1831–1931* (London: British Association for the Advancement of Science, 1931), appendix 2, pp. 305–22.
14. Merrifield, ‘Experiments’, p. 80.
15. Frederic Manning, *The Life of Sir William White* (London: John Murray, 1923), p. 68. This passage is in the context within which the results Froude deduced from model ship experiments are referred to in connection with William White’s book, *Manual of Naval Architecture* published in 1877.
16. R. W. L. Gawn, ‘Historical notes on investigations at the Admiralty experiment works, Torquay’, *TINA*, vol. 83 (1941), pp. 80–139, appendix 1, Outline description of the Torquay tank and equipment, pp. 115–17.
17. W. Froude, ‘Observations and suggestions on the subject of determining by experiment the resistance of ships’, December 1868, collected in Westcott Abell, ‘William Froude’, *TINA*, vol. 76 (1934), pp. 243–56, appendix.
18. To be accurate, he began his remark with: ‘Now, Sir, you [chairman] have spoken of very minute models, speaking specifically of one about 24 inches, or something of that kind.’ Merrifield, ‘Experiments’, p. 85. Interpolation is mine. The chairman on this occasion was John Scott Russell; the actual date of the remark was 7 April 1870.
19. W. Froude, ‘On experiments with H. M. S. “Greyhound” ’, *TINA*, vol. 15 (1874), pp. 36–73. The quotation about amateur inventors is from Nathaniel Barnaby, ‘On mechanical invention in its relation to the improvement of naval architecture’, *TINA*, vol. 1 (1860), pp. 145–59. According to Barnaby, amateur inventors claimed 272 out of 292 patents on ships accepted during the period from 1618 to 1852. They had been people of all kinds: colonels, graduates of universities, barristers, coal-merchants, wool-dealers, agricultural machinists, upholsterers, goldsmiths, dyers, coach-makers, toy-makers, fruiterers, tallow-chandlers, brewers, and so on.
20. Abell, ‘William Froude’, p. 253. The statement was made on 10 July 1934.
21. F. P. Purvis, ‘On a proposed experimental tank’, *Zosen Kyokai Nenpo*, no. 6, December (1902), pp. 37–43.
22. Ibid.
23. See discussion appended to Thornycroft, ‘On the resistance opposed by water’, pp. 148–54; ‘William Froude’, *Nature*, 19 June (1879), pp. 169–73. For Froude’s works, see Institution of Naval Architects (ed.) *The Papers of William Froude, 1810–1879* (London: Institution of Naval Architects, 1955). Also, in Japanese, details can be found in the biography of W. Froude by Isamu Yoshioka, ‘William Froude Den: Kindai Kogaku no Akebono, Zosengaku no Chichi’ (Biography of William Froude: father of shipbuilding and the rise of modern engineering) (Tokyo: for private distribution, 1985).
24. See discussion following the paper presentation by F. P. Purvis, ‘On a proposed experimental tank’, p. 44. For a general look at the introduction of the experimental

tank to Japan at the time, see also S. Takezawa, 'Honpo shiken suiso hattatsu shoshi (1)' (Short history of the development of the experimental tank in Japan, part 1), *Nihon Zosen Gakkai Shi*, no. 592 (1978), pp. 1–8.

25. Shintaro Motora, 'An analysis of model propeller experiments', *Zosen Kyokai Kaiho*, no. 19 (1916), pp. 43–56.
26. The two numbers were represented in Motora's discourse, as *Cn* and *Cd* respectively. The 'turning moment' in Motora's discourse is today referred to as torque, but here the original term has been used. Also, as Motora himself admitted, the reason for increasing the importance of the propeller test in the experimental tank and, in particular, the propulsion efficiency of the propeller, was the problem of cavitation accompanying the high revolutions of the marine turbine, which was transferred to Japan about the same time. See, ibid., conclusion 1.
27. Motora's paper is presumed to have been already finished at the end of 1914. See Mitsubishi Jukogyo Nagasaki Kenkyujo Gijutsu Hokoku (Technical report of the Nagasaki Research Institute of the Mitsubishi Heavy Industry Company, referred to hereafter as Gijutsu Report), no. 33 (1968), p. 108. This report is a collection of typed primary source materials collected for compilation of the history of the Mitsubishi Heavy Industry Company. (Various corrections to the official history of the company were made after interviews with the personnel involved with model ship experiments at the time.)
28. Since Hiroshige's statement was made in relation to the early days of the Meiji era, there is a possibility that the science and technology gap had been diminishing from that period until 1916, a possibility which will be examined below.
29. Gijutsu Report, no. 33, p. 5.
30. Ibid., pp. 9–10.
31. Ibid., p. 10.
32. Ibid., pp. 10–11.
33. Ibid., pp. 8–11.
34. Ibid., p. 14.
35. The ship model at this time was a reduced scale model of 1:23.75 of the actual length of 285 feet, similar to the model used by the experimental tank of Denny and Brothers in order to confirm the accuracy and the reproduction of the measurement data. See K. Taniguchi, 'Historical review of research and development in ship hydrodynamics', paper presented at the 75th Anniversary of Nagasaki Experimental Tank 1907–1983, May (1983).
36. Gijutsu Report, no. 33, p. 97.
37. Ibid., p. 104.
38. Ibid., pp. 99–100.
39. The accurate estimated cost was 151,938 yen 60 sen. Calculated from the *Annual Report of Mitsubishi Nagasaki Shipyard* (1909), pp. 23–4.
40. In 1918 a darkroom was also added.
41. *Annual Report of Mitsubishi Nagasaki Shipyard* (1907), p. 51; idem (1908), pp. 23–4.
42. The total sales here include sundry revenue account (*zatsu shunyu kanjo*) and sundry account (*zatsu kanjo*). The amount of the total sales is based on *Annual Report of Mitsubishi Nagasaki Shipyard* (1908), List of total sales (Sagyo Daka Ichiran), List of profit and loss account (Soneki Kanjo Ichiran). The percentage for the present-day total R&D cost on average is based on Science and Technology Agency, *Kagakugijutsu Yoran* (Indicators of science and technology), 2002, p. 64 (the data is for the fiscal year of 2000).
43. Gijutsu Report, no. 33, p. 22, pp. 65–93.

44. Gijutsu Report, no. 33, pp. 25–32. Motora also took the graduate course at the Science Department of Tokyo Imperial University for two years from 1910, where he studied mathematics and experimental physics. The name and year of graduation of those graduates of the Shipbuilding Department of Tokyo Imperial University who were employed by the Experimental Tank Unit during the period 1908–17 was as follows: Koshiro Shiba, 1899; Goro Kawahara, 1901; Shintaro Motora, 1905; Fukusaburo Takami, 1905. Since several persons occupied different sub-roles in Table 2.2 through promotion several times during the period, the net total number of engineers and technicians during the period was seven.
45. Also see Chapter 1. The pioneering spirit of the college was taken up in the British science magazine *Nature* in the same year. 'An engineering college in Japan', *Nature*, 3 April (1873), p. 430.
46. Ministry of the Imperial Japanese Navy (ed.) *Kaigun Seido Enkaku* (History of the naval institutions) (Tokyo: Kaigun Sho, 1938), vol. 2, p. 459. Although the official name was the Experimental Warship Tank (*Kankei Shiken Jo*), here the word experimental tank is used for convenience sake.
47. Zosen Kyokai, *Nihon Kinsei Zosen Shi* (History of Japan's modern shipbuilding) (Tokyo: Zosen Kyokai, 1935), Taisho era, p. 635.
48. Kaigun Daijin Kanbo Kiroku Ko (Record Office of the Secretary to the Navy Minister), 'Meiji 39 Nen Gaikoku Chuzaiin Hokoku' (Report of personnel stationed overseas, 1906), vol. 2 (this report will be abbreviated to Inagawa Report hereafter).
49. Inagawa Report (this report has no page numbers).
50. In (e) of (B), five items such as the tank for melting paraffin wax as the material for ship models were included.
51. Inagawa Report.
52. Ibid.
53. Ibid.
54. Ibid.
55. Ibid.
56. The oldest navy yard in Japan was the Yokosuka Navy Yard originating in 1864 under the superintendence of the Tokugawa shogunate, where 'technical staff … consisted entirely of French naval constructors, with their own foremen and leading hands under them, lent by the French government'. And the first Japanese naval vessel built in this yard (the *Seiki*) was 'designed by Monsieur Verny, the head of the French naval architects in the yard, and was built and engined by the French naval architects and engineers'. In contrast, around a time when the first Japanese composite naval vessel (the *Katsuragi*) was built and launched in 1885 by the yard, 'two foremen were lent by the British government'. Motoki Kondo, 'Progress of naval construction in Japan', *TINA*, vol. 53, pt 2 (1911), pp. 50–60. For the French connection of the Yokosuka Navy Yard in terms of technology learning in its early day, also see Yokosuka Navy Yard (ed.) 'Gijutsukan oyobi Shokko Kyoiku Enkaku Shi' (The history of the training of engineers and skilled workers), n.d.
57. Inagawa Report.
58. Ibid.
59. Ibid.
60. 'Rational' here is used to mean transcending the short-term advantages and partiality for a single agent and expanding the long-term advantages for the collective whole.

61. Gijutsu Report, no. 33, pp. 18–19.
62. The Ministry of the Imperial Japanese Navy (ed.) *Kaigun Seido Enkaku*, vol. 2, p. 145. According to the ordinance, the Parliamentary Vice-Minister of the Navy was not able to deal with anything pertaining to 'military secrets and regulations' (ibid.). In August 1924, the post was revised and came to be called Kaigun Seimu Jikan by the Imperial Ordinance no. 181 of 12 August 1924.
63. This is certainly still only a general approximation to reality. Further corroboration and elaboration will be made in Chapter 3, by describing and analyzing an independent case, the marine turbine whose transfer to Japan took place almost the same time.
64. To be fair, attempts at overcoming the stereotypical view of government-directed industrialization have already been made. See, for example, Richard J. Samuels, *'Rich Nation, Strong Army': National Security and Technological Transformation of Japan* (Ithaca: Cornell University Press, 1994). The background of these attempts seems to have something to do with viewpoints questioning the classical dichotomy of civilization and culture where science and technology is advancing, developing and being popularized as the most important part of civilization. The invalidity of this classical dichotomy was usually demonstrated in the transfer of science and technology to the developing countries. See, for example, Jacques Perrin, *Les Transferts de Technologie* (Paris: La Découverte/Maspéro, 1983).
65. On the development of policy for national R&D, see Chikayoshi Kamatani, *Gijutsu Taikoku Hyakunen no Kei: Nippon no Kindaika to Kokuritsu Kenkyu Kikan* (The road to techno-nationalism: Japanese modernization and national research institutes from the Meiji era) (Tokyo: Heibonsha, 1988).
66. The contemporary factors surrounding Mitsubishi that reinforced this intrinsic effort to set up an R&D organization before the wartime mobilization, such as market structure and labour processes, form a separate topic. For this, see Miwao Matsumoto, *Fune no Kagaku Gijutsu Kakumei to Sangyo Shakai: Igirisu to Nihon no Hikaku Shakaigaku* (The scientific and technological revolution in shipbuilding and industrial society in the age of imperialism: a comparative sociology of Britain and Japan) (Tokyo: Dobunkan, 1995), ch. 8.
67. To avoid this possibility, it is vital to make a systematic international comparison that goes beyond the description of cultural items differing in appearance. Here lies the reason why this book makes a thorough investigation of factors which were involved in the transfer of a particular technology both in Britain and Japan (see ibid.). For a study carried out by a sociologist who drew attention to the danger of international comparison without detailed case studies, see K. Ariga, 'Josetsu kindaika to dento' (Introduction to modern and traditional Japan), first published in 1963, in *Ariga Kizaemon Chosakushu* (Kizaemon Ariga's collected writings), vol. 4 (Tokyo: Miraisha, 1976), pp. 117–42.

## 3 Technology Gatekeepers Combine: The Emergence of the Japanese Military-Industrial-University Complex

1. Charles A. Parsons, 'Improvements in the mechanism for propelling and controlling steam vessels', Patent record no. 394 AD 1894 (kept by Tyne and Wear Archives Service, Newcastle-upon-Tyne). As for events before this patent, see W. Garrett Scaife, 'Charles Parsons' experiments with rocket torpedoes: the precursors of the steam turbine', *Transactions of the Newcomen Society for the Study of the History of Engineering and Technology*, vol. 60 (1991), pp. 17–29.

2. In particular, how to cope with cavitation caused by the high revolutions of propellers was a problem the full answer to which was unknown even to the original inventor at the time (essentially the situation is the same today). For the problem and the countermeasures adopted by the original inventor, Charles A. Parsons, see C. A. Parsons, 'The application of the compound steam turbine to the purpose of marine propulsion', *TINA*, vol. 38 (1897), pp. 232–42.
3. It is usually said that the *Sakuramaru*, completed on 9 October 1908, was the first ship with a domestically produced steam turbine. However, to be accurate, the marine steam turbine installed in this ship was not fully domestically produced, since it was produced in accordance with blueprints directly imported from Britain. See Nippon Hakuyo Kikan Gakkai Hakuyo Kikan Chosa Kenkyu Iinkai (Research Committee of the Marine Engineering Society in Japan, abbreviated to RCMESJ hereafter) (ed.) 'Nippon Hakuyo Kikan Shi Joki Tabin Hen Soko' (An unpublished manuscript of the history of marine engineering in Japan: the steam turbine), 3.1.2.(3).
4. It is generally supposed that a time lag of this sort was more than thirty years on average for Japan at the time.
5. The first turbine-driven naval vessel was the *Mogami* as will be mentioned later.
6. The usual response to the question is to refer to the talents of those engineers and foremen in Japan who produced the marine turbine, or to the historical accident that Japan had only slightly earlier introduced the water turbine for generators. For a reference to the talents of individuals, see Yukiko Fukasaku, 'Technology imports and the development of technological capability in the industrialization of Japan: training and research at Mitsubishi Nagasaki Shipyard 1884–1934', a doctoral thesis submitted to the University of Sussex in 1988, pp. 129–72 (a shortened version was published in book form entitled *Technology and Industrial Development in Prewar Japan*, London: Routledge, 1992). For a reference to the historical accident, see Hiroo Kato, '1890 nen kara 1945 nen madeno Nihon no hatsudenyo suisha gijutsu no jiritsu katei' (Course of independence of Japanese water turbine technology for power generation 1890–1945), *Kagaku Shi Kenkyu*, vol. 23, no.150 (1984), pp. 110–20. For an interesting work on the original invention and the development of the water turbine within a comparative perspective between the US and France, see Edwin T. Layton, Jr, 'Millwrights and engineers: science, social roles, and the evolution of the turbine in America', in Wolfgang Krohn, E. T. Layton, Jr, and Peter Weingart (eds) *The Dynamics of Science and Technology* (Dordrecht: D. Reidel, 1978), pp. 61–87. As far as we are able to confirm based on contracts, Japan acquired the right for the licence production of the steam turbine for generators as early as 1904, which might provide a suitable topic for further consideration. See C. A. Parsons and Company Ltd, Licences from C. A. Parsons and Company Ltd to Mitsubishi Zosen Kwaisha of Tokyo, Japan (kept by Tyne and Wear Archives Service, Newcastle-upon-Tyne), n.d.
7. A focus on the interests of agents concerned or on their networks has made possible inquiries into the social shaping of science and technology. See, for example, Barry Barnes, *Interests and the Growth of Knowledge* (London: Routledge, 1977); Michel Callon, John Law and Arie Rip (eds) *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World* (London: Macmillan, 1986); B. Barnes, David Bloor and John Henry, *Scientific Knowledge: A Sociological Analysis* (Chicago: University of Chicago Press, 1996). Most of these inquiries tend to take up one of the latest contemporary topics in science as case materials. For example, see Bruno Latour and Steve Woolgar, *Laboratory Life: The Social Construction of*

*Scientific Facts* (Beverly Hills: Sage, 1979); Michael Mulkay and Nigel G. Gilbert, *Opening Pandora's Box: A Sociological Analysis of Scientists' Discourse* (Cambridge: Cambridge University Press, 1984); Harry M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London: Sage, 1985); Brian Martin and Evelleen Richards, 'Scientific knowledge, controversy, and public decision making', in Sheila Jasanoff, Gerald E. Markle, James C. Petersen and Trevor J. Pinch (eds) *Handbook of Science and Technology Studies* (London: Sage, 1995), pp. 506–26; Karin Knorr Cetina, 'Laboratory studies: the cultural approach to the study of science', in ibid., pp. 140–66; Karin Knorr Cetina, 'Laboratory studies and the constructivist approach in the study of science and technology', *Japan Journal for Science, Technology & Society*, vol. 2 (1993), pp. 115–50. At least two events seem to have opened the door to applying this sociological approach to technology: first, the breaking of the tradition assuming cognitive dependence of technology upon science; secondly, direction of attention to conceptualizing cognitive change in technology itself. For the former, see Barry Barnes, 'The science–technology relationship: a model and a query', *Social Studies of Science*, vol. 12, no. 2 (1982), pp. 166–72; and for the latter, see Rachel Laudan (ed.) *The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?* (Dordrecht: D. Reidel, 1984). For case studies based on this approach, see Donald Mackenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, Mass.: MIT Press, 1990); Wiebe E. Bijker, Thomas P. Hughes and Trevor J. Pinch (eds) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, Mass.: MIT Press, 1987); Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins University Press, 1983); David E. Nye, *Electrifying America: Social Meaning of a New Technology, 1880–1940* (Cambridge, Mass.: MIT Press, 1990), and others. However, we have to be careful about hasty application of these concepts, particularly in describing and analyzing technology transfer, because the composite structure involved in the technology transfer provides, in turn, an indispensable context within which alone the meaning of these concepts can be concretely modified.

8. The Navy played a major part in the introduction of Western science and technology into Japan from the early Meiji period, and was indispensable not only to national defence and industrial policy (*Fukokukyohei Seisaku*) but also to national interest in general, as suggested in Chapter 2. The Navy's influence on scientific and technological development in Japanese industrialization was by no means uniform over time, however, and the implications with respect to industrial policy, for example, were therefore not uniform. This entails a corollary that stereotypical views of Japanese industrial policy or industrialization as being government-directed for the sole purpose of catching up with advanced Western sciences and technologies result from the lack of a full understanding of the behaviour pattern of the public sector (the Navy in this case). *Fukokukyohei* means 'Rich Nation, Strong Army' and *Shokusankogyo* means the promotion of industrialization. For a study focusing on the former aspect of Japanese industrial policy since the Meiji Restoration, see Richard J. Samuels, *'Rich Nation, Strong Army': National Security and the Technological Transformation of Japan* (Ithaca: Cornell University Press, 1994); for a study focusing on the latter aspect of Japanese industrial policy based on the history of national research institutes of Japan since the Meiji Restoration, see Chikayoshi Kamatani, *Gijutsu Taikoku Hyakunen no Kei: Nippon no Kindaika to Kokuritsu kenkyu Kikan* (The road to techno-nationalism: Japanese modernization and national research institutes from the Meiji era) (Tokyo: Heibonsha, 1988). Also

see Miwao Matsumoto, 'Review: The road to techno-nationalism: Japanese modernization and national research institutes from the Meiji era', *Historia Scientiarum*, no. 38 (1989), pp. 75–80. Understandably, several efforts to revise the stereotypes of government-directed industrialization in Japan have been made by focusing upon, for example, local industries as mentioned in Chapter 1 (for a recent effort of this direction, see Jun Suzuki, *Meiji no Kikai Kogyo* (Machinery industry in the Meiji period) (Kyoto: Minerva Shobo, 1996). Apart from such efforts, however, a fresh reconsideration of government-directed industrialization by means of a detailed sociological inquiry into the behaviour pattern of the public sectors itself is needed to understand its role as technology gatekeeper. The understanding obtainable from such an inquiry will not only reveal a much more complex structure of contemporary Japanese industrial policy than is usually supposed, but also enable us to gain broader insights into the social function of the public sector in gatekeeping.

9. Nippon Hakuyo Kikan Shi Henshu Iinkai (Editorial Board for the History of Marine Engineering in Japan, abbreviated to EBHME hereafter) (ed.) *Teikoku Kaigun Kikan Shi* (The history of Imperial Japanese Navy marine engines) (reprinted Tokyo: Hara Shobo, 1975), Ge Kan, pp. 421–2.
10. For the first article on the steam turbine in that journal, see Makoto Saito, 'Steam turbine ni tsuite' (On steam turbines), *Zosen Kyokai Kaiho*, no. 4 (1906), pp. 31–8; Seiichi Terano, ' "Tabain" sen ni tsuite' (On vessels propelled by turbines), *Zosen Kyokai Kaiho*, no. 4 (1906), pp. 57–9. Although the Engineering Society (Kogaku Kai) established in 1879 was partly concerned with marine engineering, it was much later that the first article on the steam turbine appeared in an official journal of the society. See, for example, Masao Kamo, 'Joki tabin no hattatsu' (The development of the steam turbine), *Kogaku Kai Shi*, vol. 379 (1914), pp. 565–79, vol. 380 (1915), pp. 4–14, vol. 382 (1915), pp. 93–107, vol. 383 (1915), pp. 134–44, vol. 384 (1915), pp. 161–8.
11. EBHME, *Teikoku Kaigun Kikan Shi*, p. 421.
12. This fact appears all the more noteworthy if we take into account the fact that a proposal for adopting the British-designed Parsons turbine had been made earlier to the Imperial Japanese Navy by A. F. Yarrow who had had a strong connection with the Imperial Japanese Navy in exporting boilers. For his proposal, see EBHME, *Teikoku Kaigun Kikan Shi*, pp. 426–8.
13. On the invention and the development of the American Curtis type, see Euan F. C. Somerscale, 'The vertical Curtis steam turbine', *Transactions of the Newcomen Society for the Study of the History of Engineering and Technology*, vol. 63 (1992), pp. 1–52.
14. EBHME, *Teikoku Kaigun Kikan Shi*, p. 423.
15. Ibid., p. 424.
16. After returning to Japan in 1907, he became chief of the marine engine division of the Yokosuka arsenal of the Imperial Japanese Navy in 1908 and was appointed Rear Admiral in 1910. In 1914 he retired due to the so-called Siemens incident.
17. EBHME, *Teikoku Kaigun Kikan Shi*, p. 430.
18. Ibid., pp. 430–2. Interpolations are mine.
19. Prices of the Curtis turbines included two main bearings and throttle valve governors, and those of the Parsons turbines included propellers, starting valves, pipes and oil arrangements.
20. EBHME, *Teikoku Kaigun Kikan Shi*, p. 438.
21. Ibid.
22. Ibid., p. 423.

23. Ibid., p. 445.
24. Ibid., pp. 445–6.
25. Immediately after the contract with the Foreriver Shipbuilding Company in 1906, Yoichi Inagawa, an engineer of the Imperial Japanese Navy, was dispatched to the company. His voluminous technical report, submitted to the Imperial Japanese Navy, laid the foundation for the impulse turbine design taught later at the Japanese Naval College. Ryutaro Shibuya, 'Kyu Kaigun Gijutsu Shiryo' (Technical documents of the Imperial Japanese Navy) (Tokyo: Seisan Gijutsu Kyokai, for private distribution, 1970), vol. 1, p. 101. Ryutaro Shibuya was one of the key persons of the Navy in introducing and improving the marine turbine after this time, and later became the director of the Technical Headquarters of the Imperial Japanese Navy. He left more than 4000 primary source documents (not collected in the documents mentioned above), which are being catalogued at the Shibuya archives. See Chapter 6.
26. EBHME, *Teikoku Kaigun Kikan Shi*, p. 454.
27. Ibid., pp. 454–5. As will be mentioned later, this contract was made between the Parsons Marine Steam Turbine Company, and the Mitsubishi Limited Partnership (Mitsubishi Goshi Kaisha) and the Imperial Japanese Navy. Mitsubishi Nagasaki Shipyard belonged to the Mitsubishi Limited Partnership. For the origin of Mitsubishi Nagasaki Shipyard, see Yoh Nakanishi, *Nihon Kindaika no Kiso Katei: Mitsubishi Nagasaki Zosen Sho to sono Roshi Kankei, 1855–1900* (Emergence of a modern Japanese enterprise and its industrial relations – Mitsubishi Shipyard, 1855–1900), 3 vols (Tokyo: Tokyo Daigaku Shuppan Kai, 1982, 1983, 2003).
28. EBHME, *Teikoku Kaigun Kikan Shi*, p. 454.
29. These data were based on a full-scale survey of factories made by the No Shomu Sho (Ministry of Agriculture and Commerce), the prewar counterpart of the Ministry of Trade and Industry.
30. Naval vessels that, from the record of the *Annual Report of the Naval Ministry* (Kaigun Sho Nenpo), may be judged to have been completed by the 'knockdown' way of production are not included here. Naval vessels under construction are also omitted.
31. The roles played by these two firms in accumulating the technology base of the marine turbine should be considered in their own light apart from the orders for naval vessels from the Imperial Japanese Navy, which will be analyzed separately later by focusing on Mitsubishi. This is because the production know-how not contained in blueprints was 'kept secret' from private firms by the Navy. See 'Inagawa Zosen Dai Gishi Gaikoku Chuzaiin Hokoku Dai 267 Go' (A foreign technical report no. 267 by Navy Chief Engineer Yoichi Inagawa, submitted to the Imperial Japanese Navy), 18 February 1907, Navy Minister's Secretariat, the Imperial Japanese Navy.
32. EBHME, *Teikoku Kaigun Kikan Shi*, pp. 452–3, pp. 455–6. In the case of the *Kawachi*, the shell was produced separately by the Yokosuka arsenal of the Imperial Japanese Navy.
33. See also Chapter 6.
34. The description of the particulars of the first *Kanpon* type marine steam turbine is based upon RCMESJ, 'Nippon Hakuyo Kikan Shi', Kaigun Hen, appended tables. The steam temperature and pressure are given at the outlet of boilers. Dr Seikan Ishigai, the former president of the Marine Engineering Society of Japan, gave me important technical advice in interpreting the voluminous blueprints of this *Kanpon* turbine.

35. If we trace the potential production ability of shipbuilding companies back to the financial aid given by the Japanese government through the Shipbuilding Promotion Act (Zosen Shorei Ho) and the Shipping Promotion Act (Kokai Shorei Ho) issued in 1896 (to be mentioned later), the competition in the market is half-controlled competition in the long run. In general, similar public policies designed to give financial aid to leading shipbuilding companies have been common to most industrial societies, which might suggest the universal existence of half-controlled competition in the shipbuilding industry.
36. A 'state interventionist' rationality in this context generally indicates attaining a socially desirable state by the intervention of public sector agencies, including the military, rather than an approach confined to hiring and fiscal policies alone. A 'market' rationality, on the other hand, generally indicates achieving the same goal with minimum intervention on the part of the public sector and the maximum degree of market operation.
37. Within only five years of the Imperial Japanese Navy's decision to adopt the marine turbine in 1905, the following comprehensive information on the marine turbine was collected and intensively analyzed by the Navy: a theoretical analysis of the infinitesimal heat drop; mechanical loss; layout and installation, and so on. See 'Kawaji Kaigun Kikan Shosa Sintatsu Dai 137 Go' (A foreign technical report no. 137 by Engine Lieutenant-Commander Kawaji, submitted to the Imperial Japanese Navy), 18 January 1910, Naval Minister Secretariat, Imperial Japanese Navy; 'Kawaji Kaigun Kikan Shosa Shintatsu Dai 194 Go' (A foreign technical report no. 194 by Engine Lieutenant-Commander Kawaji, submitted to the Imperial Japanese Navy), 5 May 1910, Naval Minister Secretariat, Imperial Japanese Navy. As far as we are able to confirm at present, the first such technical report on the marine turbine by engineers of the Navy stationed overseas was submitted to the Navy in 1899. See 'Fujii Kaigun Kikan Shokan Shintatsu' (A foreign technical report by Engine Lieutenant-Commander Fujii submitted to the Imperial Japanese Navy), 28 February 1899, Naval Minister Secretariat, Imperial Japanese Navy.
38. When there is only a small technology gap, for example, 'multiple invention' may take place, although these actual institutional arrangements vary from one society to another. As for the different milieu in which the De Laval, Parsons, Curtis and Rateau turbines developed nearly simultaneously, see Edward Constant II, *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980), pp. 63–82. For a critical appraisal of the concept of 'multiple invention' itself, see *idem.*, 'On the diversity and co-evolution of technological multiples: steam turbines and Pelton water wheels', *Social Studies of Science*, vol. 8, no. 2 (1978), pp. 183–210.
39. Similar rationality and active attitude observed in an independent case of the transfer of the experimental tank may also support this. See Chapter 2.
40. From the viewpoint of Western countries, these wars, particularly the Russo-Japanese War, also taught them important lessons about marine technology, including battleship design. For this, see for example, 'Le materiel naval et la bataille de Tsou-Sima', *Le Temps*, 13 February (1906); *Edinburgh Review*, no. 419 (1907), pp. 185–91. On contemporary British battleship design, see David K. Brown, 'British battleship design, 1840–1904', *Interdisciplinary Science Reviews*, vol. 6, no. 1 (1981), pp. 79–93. On contemporary British naval policy, giving the background of the Russo-Japanese War, see Jon Tetsuro Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (London: Routledge, 1993), pt 1.

41. Several innovative evolutionary economists have tried to explain technological innovations within or without the framework such as production function, input–output analysis, which might lead to the opening of the black box. 'National styles of innovations' proposed by Christopher Freeman, among others, might certainly have some relevance to a study beyond 'black boxism' (Richard Whitley) in terms of technology, but unfortunately the concept seems to be too schematic to pinpoint the complex subtleties of the role played by technology gatekeepers as elucidated above. See C. Freeman, *Technology Policy and Economic Performance: Lessons from Japan* (London: Pinter, 1987). Also see Richard Nelson and Sidney G. Winter, *An Evolutionary Theory of Economic Change* (Boston: Harvard University Press, 1982); and Christopher Freeman and Luc Soete (eds) *New Explorations in the Economics of Technical Change* (London: Pinter, 1990).
42. The transfer of marine steam turbine engines occurred within the context of the parallel link between Japan's private sector and Britain. For a contemporary view of Japanese shipbuilding circles on the marine turbine, see the official view of the journal, *Kogyo*, 'Kaiun gyosha fukaku joki tabin kikan ni chumoku seyo' (Consider the steam turbine carefully, shipping traders!), *Kogyo*, no. 15 (1910), pp. 1–3. Another important use of the steam turbine is for power plants. The social significance of the steam turbine for power plants is worthy of distinct treatment from the marine steam turbine in connection with the development and the introduction of generators and electric motors. Therefore, for the present, the argument will not go into the details of the steam turbine for power plants. For a study treating the electrification of Japanese factories which might provide a background for such problems, see Ryoshin Minami, *Power Revolution and Industrialization of Japan, 1885–1940* (Tokyo: Kinokuniya, 1987). For the electrification of society within different national contexts, see Hughes, *Networks of Power*; Alain Beltran, 'Du luxe au cœur du système: électricité et société dans la région parisienne (1880–1939)', *Annales*, 44e année, no. 5 (1989), pp. 1113–35, and others. Also see Edmund N. Todd, 'A tale of three cities: electrification and the structure of choice in the Ruhr, 1886–1900', *Social Studies of Science*, vol. 17, no. 3 (1987), pp. 387–412; Robert U. Ayres, *The Next Industrial Revolution: Reviving Industry through Innovation* (Cambridge, Mass.: Ballinger, 1984), pp. 110–25.
43. *Annual Report of the Mitsubishi Nagasaki Shipyard* (Mitsubishi Zosenjo Nenpo), 1905, p. 45.
44. Early Parsons Plant to Mitsubishi (kept by NEI Parsons, Ltd, Newcastle-upon-Tyne). To be accurate, the company exporting these turbine-generators was not the Parsons Marine Steam Turbine Company at Wallsend mentioned above but C. A. Parsons and Company at Heaton set up by C. A. Parsons in 1889 for the production of turbine-generators and steam turbines for land purposes.
45. Kozo Yokoyama, 'Mitsubishi Juko Shashi Genko' (A manuscript of the history of Mitsubishi Heavy Industry, Ltd), n.d., p.3.
46. Iwasaki Ke Denki Kanko Kai (ed.) *Iwasaki Yanosuke Den* (A biography of Yanosuke Iwasaki), Gen Kan (Tokyo: Tokyo Daigaku Shuppankai, 1971), pp. 323–4.
47. Ibid., p. 325.
48. Ibid., p. 324. Interpolations are mine.
49. On the details of the *Tenyomaru*, see Seiichi Terano and Chuzaburo Shiba 'Remarks on the design and service performance of the transpacific liners *Tenyo Maru* and *Chiyo Maru*', *TINA*, vol. 53, pt 2 (1911), pp. 184–92. Also see, Tetsuro Nakaoka, 'On technological leaps of Japan as a developing country, 1900–1940', *Osaka City University Economic Review*, no. 22 (1987), pp. 1–25.

50. Taijiro Asano and Ryozo Asano, *Soichiro Asano* (Tokyo: Asano Bunko, 1923), pp. 490–1.
51. 'Shiota Taisuke Jijoden' (The autobiography of Taisuke Shiota) (based on an interview by Masaki Uchiyama for private distribution, 1938), p. 315.
52. Samuel Pringle even boarded the ship as a supervising engineer when it was transferred to Yokohama. The story of Pringle is based upon the *Annual Report of Mitsubishi Nagasaki Shipyard*, 1907, pp. 63–4; Mitsubishi Nagasaki Zosenjo, *Mitsubishi Nagasaki Zosenjo Shi* (1) (The history of the Mitsubishi Nagasaki Shipyard: 1) (Nagasaki: Mitsubishi Nagasaki Zosenjo, 1928), pp. 121–2.
53. Based on the *Annual Report of the Mitsubishi Nagasaki Shipyard*, 1906, p. 19.
54. Seiichi Terano, 'Tabain sen ni tsuite' (On turbine ships), *Zosen Kyokai Kaiho*, no. 4 (1906), pp. 57–9.
55. The expression within quotation marks is quoted from Shigeichi Yadori, *Shoda Heigoro* (Tokyo: Taikyosha, 1932), p. 70.
56. Kaiun Shincho Hoho Chosa Iinkai ni okeru Shoda Heigoro Kojutsu (Presentation by Heigoro Shoda at the Research Committee on Shipping Expansion held on 6 February 1895), kept by University of Tokyo Library.
57. Prescribed by Clause 4 of the law. See Law No. 16, Zosen Shorei Ho o Sadamu (Ordaining the Shipbuilding Promotion Law), Classified public record (Kobun Ruiju), file 20, vol. 24, 23 March 1896. According to its initial plan, (1) government subsidies were to be given only to iron or steel steamers of 1000 gross tons or more and (2) the rate of subsidy was 20 yen per 1 ton gross (see Kaiun Shincho Hoho Chosa Iinkai ni okeru Shoda Heigoro Kojutsu, above). When the law was actually enacted, the limit for these subsidies was changed to 700 gross tons or more. See Clause 3 of the Law no. 16 mentioned above. The Shipping Promotion Law was revised in 1899. See Law No. 96, Kokai Shorei Ho chu o Kaisei Su (Revising the Shipping Promotion Law), Classified public record, file 23, vol. 32, 28 March 1899.
58. There was another company that introduced the marine turbine to Japan: the Kawasaki Shipbuilding Company made a contract to introduce the production technology of the marine turbine later, on 18 January 1907. But the marine turbine on this occasion was not Parsons' design but the Curtis turbine, one of the improved types of the Parsons turbine, which was first produced by the International Curtis Marine Turbine Company in the US. And Kawasaki completed the first production of the marine turbine in 1912, four years after Mitsubishi's first production. Because the aim of this chapter is to focus on the earliest transfer of the first product innovation by private companies, we will set aside the history of the introduction of the Curtis turbine for the present. What is mentioned above is based on Kawasaki Heavy Industry Ltd, 'Kawasaki Juko Joki Tabin Hattatsu Shi: Senzen Hen' (A manuscript of the history of steam turbine development in Kawasaki Heavy Industry Ltd: prewar period), 1942 (a manuscript kept by Dr Yasuo Takeda). The history of turbine development within a comparative perspective, whether the working fluid is steam or water, seems to deserve separate consideration. See Layton, Jr, 'Millwrights and engineers'; Constant, *The Origins of the Turbojet Revolution*.
59. The *Tenyomaru* and *Shunyomaru* were, respectively, the 190th and the 203rd ships constructed by the shipyard. Based on Mitsubishi Zosen, *Sogyo Hyakunen no Nagasaki Zosenjo* (A centenary history of the Nagasaki Shipyard) (Tokyo: Mitsubishi Zosenjo, 1957), p. 171: appendix: the list of main products (Shuyo Seihin Ichiran Hyo) 1; the list of main products 2. Strictly speaking, the

*Sakuramaru*, completed on 9 October 1908, was the first ship with a domestically produced steam turbine. Since this ship appears to have been built as a converted cruiser for the Navy, we set aside this ship to focus upon merchant ships. For the strategy of the Imperial Japanese Navy in introducing this foreign technology, see earlier in this chapter.

60. As regards the dependence on imported blueprints at this time, I was able to obtain an insight into contemporary practice by interviewing a former president of the Marine Engineering Society of Japan, Dr Seikan Ishigai, on 11 June 1987.
61. For a taxonomy of the concept of rationality, see John H. Goldthorpe, 'Rational action theory for sociology', *British Journal of Sociology*, vol. 49, no. 2 (1998), pp. 167–92. In his taxonomy, rationality, here means weak, situational, special rationality, and non-rationality means the non-existence of rationality in this sense, though this kind of taxonomic argument contains no substantial information enabling us to specify the importance of the entrepreneurship of technology gatekeepers. In line with classical sociological tradition, the importance of the definition of situation given by agents seems to hold researchers' attention again in action theories (for example, Special issue, *European Sociological Review*, vol. 12, no. 2 (1996), though the above lack of specification can be observed in this emphasis on the definition of situation too).
62. For this, see Constant, *The Origins of the Turbojet Revolution*, pp. 63–82.
63. For a theoretical consideration of the process by an economist, see Nathan Rosenberg, *Inside the Black Box: Technologies and Economies* (Cambridge: Cambridge University Press, 1982), pp. 120–40.
64. 'The economy of steam turbines in cruisers', *Engineering*, 18 November (1904), pp. 689–92.
65. Ibid.
66. For the connection of the steam turbine with the development of the turbojet engine, see Constant, *The Origin of the Turbojet Revolution*.
67. C. A. Parsons, 'The application of the marine steam turbine and mechanical gearing to merchant ships', *TINA*, vol. 52 (1910), pp. 168–72.
68. Yokoyama, 'Mitsubishi Juko Shashi Genko' (Manuscript history of Mitsubishi), pp. 3–5.
69. Ibid., p. 4.
70. Nippon Hakuyo Kikan Shi Henshu Iinkai, pp. 454–5.
71. Ibid., p. 430.
72. Based on Mitsubishi Nagasaki Zosenjo Keireki Sho (Collection of *Curriculum Vitae*), n.d. (kept by Mitsubishi Nagasaki Shipyard)
73. There is a vast amount of literature in development economics which deals with this topic in technology transfer. To cite only a few examples here, see Richard R. Nelson, 'Less developed countries – technology transfer and adaptation: the role of the indigenous science community', *Economic Development and Cultural Change*, vol. 23, no. 1 (1974), pp. 61–77; Lynn K. Mytelka, 'Stimulating effective technology transfer: the case of textiles in Africa', in Nathan Rosenberg and Claudio Frischtak (eds) *International Technology Transfer: Concepts, Measures, and Comparisons* (New York: Praeger, 1985), pp. 77–126; J-J. Salomon, A. Lebeau and C. Sachs-Jeantet (eds) *The Uncertain Quest: Science, Technology and Development* (Tokyo: United Nations University Press, 1994), and so on. Taking the subject one step further, there is often the problem of a colonial context, within which imbalance in various terms between advanced and developing countries is revealed. See, for example, P. Petitjean, C. Jami and A. M. Moulin (eds) *Sciences and*

*Empires: Historical Studies about Scientific Development and European Expansion* (Dordrecht: Kluwer Academic, 1992); Lewis Pyenson, *Civilizing Mission: Exact Science and French Overseas Expansion, 1830–1940* (Baltimore: Johns Hopkins University Press, 1993); Jacques Gaillard, V. V. Krishna and Roland Waast (eds) *Scientific Communities in the Developing World* (New Delhi: Sage, 1997); Deepak Kumar, *Science and the Raj, 1857–1905* (New Delhi: Oxford University Press, 1997), and so on.

74. This department of the Imperial University originated from that of the University of Tokyo established in 1877, which further originated from the Engineering College (Kobu Daigakko), established in 1873. For a study on this initial college based upon primary source materials, see Yasushi Kakihara, 'Kindai nihon no kogaku kyoiku ni okeru kagaku to jicchi no sokoku' (Science versus practice in engineering education in modern Japan), *Japan Journal for Science, Technology and Society*, vol. 5 (1996), pp. 1–20. Since there were many changes in the name of the higher engineering educational system, the name 'Imperial University of Tokyo' or 'Imperial University' is used here, depending upon the context.
75. Shoko Ofuku (Documents of correspondence), 1884 (kept by University of Tokyo), Ko Go, p. 125.
76. Tokyo Daigaku Hyakunen Shi Henshu Iinkai (ed.) *Tokyo Daigaku Hyakunen Shi* (A centenary history of the University of Tokyo) (Tokyo: Tokyo Daigaku Shuppan Kai, 1984), Shiryo 1, p. 88.
77. Shoko Ofuku (Documents of correspondence), 1884 (kept by University of Tokyo), Ko Go, p. 125.
78. Tokyo Daigaku Hyakunen Shi Henshu Iinkai (ed.) *Hyakunen Shi*, Shiryo 2, p. 535.
79. Okurasho (ed.) 'Kobusho Enkaku Hokoku' (A report on the origin of the Ministry of Engineering, Tokyo, 1889), collected in Hyoe Ouchi and Takao Tsuchiya (eds) *Meiji Zenki Zaisei Keizai Shiryo Shusei* (Collection of the historical documents on finance and economy in the early Meiji period), vol. 17, pt 1 (Tokyo: Meiji Bunken Shiryo Kanko Kai, 1964), p. 395. Interpolations by author.
80. Saiichiro Uchimaru, *Joki Tabin* (Steam turbine) (Tokyo: Maruzen, 1908).
81. If we consider change in the value of the currency from 1894 to 1911 in accordance with various price indices, the cost becomes even less than one-ninth of the sum spent by Britain. This estimation is based on various price indices given by B. R. Mitchell and P. Deane, *Abstract of British Historical Statistics* (Cambridge: Cambridge University Press, 1962). pp. 471–6.
82. Studies on the aspects of the risk-taking entrepreneurship in Japanese industrialization started from Schumpeterian tradition (for example, J. Hirshmeier, *The Origins of Entrepreneurship in Meiji Japan* (Cambridge, Mass.: Harvard University Press, 1964), though they have tended to focus upon biographies of successful businessmen without connecting them with institutional patterns of behaviour and the risk-avoiding strategy of the public sector including the military. Unfortunately, reliable, detailed and comprehensive studies on the military-industrial-university complex in prewar Japan have not yet been attempted.

## 4 'Spin-on' and Latecomers' Advantages Reconsidered: British Development and Japanese Transfer in Social Context

1. L. F. Haber, *The Chemical Industry during the 19th Century* (Oxford: Oxford University Press, 1958); L. S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876–1926* (Cambridge: Cambridge University Press, 1985); G. Wise, 'Ionists in industry: physical chemistry at General Electric, 1900–1915', *Isis*, vol. 74, no. 271 (1983), pp. 7–21; G. Meyer-Thurow,

'The industrialization of invention: a case study from the German chemical industry', *Isis*, vol. 73, no. 268 (1982), pp. 363–81; F. Pfetsch, 'Scientific organization and science policy in Imperial Germany, 1871–1914: the foundation of the Imperial Institute of Physics and Technology', *Minerva*, vol. 8, no. 4 (1970), pp. 554–80, and others.

2. Although 'social process' is a term originating in sociology in the 1920s and usually used in the literature of social psychology, it is used here to mean the dynamic processes of multiple agents whose patterns of interaction can be observed. Agents here include both individual and collectivity. For an extension of such a wider usage of the term 'agent', see Bruno Latour, *Les microbes: guerre et paix suivi d' irréductions* (Paris: A. M. Métailié, 1984). In the biographies of scientists and engineers, there has been a striking tendency to misleadingly call all social residual factors, other than cognitive development, 'sociological'. As far as dramatic scaling up of scientific activity originating in the first half of the nineteenth century is concerned, the term 'the Second Scientific Revolution' was invented by R. Hahn to express that change based on a case study of L'Academie des Sciences in Paris. See R. Hahn, *The Anatomy of a Scientific Institution* (Berkeley: University of California Press, 1971), p. 275. On more general institutional change, see E. Mendelsohn, 'The context of nineteenth century science', in B. Z. Jones (ed.) *The Golden Age of Science: 30 Portraits of the Giants of 19th Century Science* (New York: Simon & Schuster, 1966), p. xiii ff.
3. The words of A. F. Yarrow, the Vice-President of the Institution of Naval Architects (the INA) at the discussion of a paper presented by Charles A. Parsons at the Summer Meeting of the 44th Session of the INA held on 26 June 1903. Parsons' paper appeared as 'The steam turbine and its application to the propulsion of vessels' in *TINA*, vol. 45 (1903), pp. 284–311, and Yarrow's words are ibid., p. 311.
4. For an account by someone directly involved in this event, the captain of the *Turbinia*, see C. J. Leyland, '*Turbinia* jottings', *Heaton Works Journal*, June (1935), pp. 25–32.
5. *The Times*, 27 June 1897.
6. *Invention*, 3 July 1897.
7. Ibid., 10 July 1897.
8. *Shipping Gazette of Lloyd's List*, 14 October 1897.
9. Ibid., 28 October 1897.
10. *L'Industrie*, 1 August 1897.
11. *Shipping Gazette of Lloyd's List*, 16 November 1897.
12. *Daily Mail*, 2 August 1898. To be accurate, this is a continuation of an article in the *Daily Mail* of 29 July, in which we can find a slightly more correct description.
13. *Daily Mail*, 2 August 1898.
14. Calculated from C. A. Parsons, 'The marine steam turbine from 1894 to 1910', *TINA*, vol. 53, pt 2 (1911), pp. 79–134.
15. For a topic of naval armament race taken up in the contemporary British parliament, see 'McKenna introduces navy estimates', 16 March 1909, Hansard, 5th series, II, cols., pp. 931–8, pp. 943–4.
16. Based on Parsons, 'The marine steam turbine'.
17. For a classical work by a sociologist employing this way of thinking, see Robert K. Merton, 'Fluctuations in the rate of industrial invention', *Quarterly Journal of Economics*, vol. 49, May (1935), pp. 454–74.
18. Patent Records no. 394, AD 1894 (Newcastle-upon-Tyne City Library).
19. 'The old patent law' mentioned here covers the period from 1617 to 30 September 1852. On 1 October 1852 the new patent law was enacted, which was reformed

once again in 1883. For the social process through which the old patent law was changed to the new one in 1852, see Harold Irvin Dutton, *The Patent System and Inventive Activity during the Industrial Revolution, 1750–1852* (Manchester: Manchester University Press, 1984), esp. pp. 57–68.

20. Nathaniel Barnaby, 'On mechanical invention in its relation to the improvement of naval architecture', *TINA*, vol. 1 (1860), pp. 145–59. For a pioneering work by a sociologist of technology which pointed out the decrease in the role played by gentlemen and the nobility since the mid-nineteenth century based on a reanalysis of patent applicants for vessel propulsion systems, see S. C. Gilfillan, *The Sociology of Invention* (Chicago: University of Chicago Press, 1935), p. 84.
21. The first affiliation with the Institution of Civil Engineers was as a student member and that with the Institution of Mechanical Engineers was as a graduate member. See Rollo Appleyard, *Charles Parsons: His Life and Work* (London: Constable, 1933), appendix, p. 307; Joe F. Clarke, 'An almost unknown great man: Charles Parsons and the significance of the patent of 1884', *Occasional Papers in the History of Science and Technology*, no. 4, Newcastle-upon-Tyne Polytechnic, 1984, A chronology. As for his enrolment as an 'Engineer', see Figure 4.4. He came from the Irish nobility. See Appleyard, *Charles Parsons*, pp. 304–5.
22. Isaac Todhunter, *Conflict of Studies and Other Essays on Subjects connected with Education* (London: Macmillan, 1873), pp. 18–19.
23. See M. Sanderson, *The Universities and British Industry: 1850–1970* (London: Routledge & Kegan Paul, 1972), pp. 31–60.
24. *Second Report of the Royal Commissioners on Technical Instruction*, vol. 1 (London: 1884), p. 422. Interpolation is by the author.
25. C. A. Parsons, 'The application of the compound steam turbine to the purpose of marine propulsion', *TINA*, vol. 38 (1897), pp. 232–42.
26. The descriptions are based on NEI Parsons Ltd, *NEI Parsons: A Century of Power* (Newcastle-upon-Tyne, n.d.), p. 3. When Parsons dissolved his junior partnership with Clarke Chapman and Company, there arose a patent right dispute between Parsons and that company concerning the axial flow turbine developed by Parsons while employed by the company. Against this background, Parsons was then obliged to develop another type of turbine in his new company, which eventually led to the development of the radial flow turbine.
27. NEI Parsons Ltd, *NEI Parsons*, p. 3.
28. Clarke, 'An almost unknown great man'. For the cost of the *Turbinia*, see mimeograph, 'Sir Charles Parsons' Steam Yacht, *Turbinia*', n.d., Tyne and Wear Archives Service, Newcastle-upon-Tyne, p. 2.
29. This was the amount of money paid to Parsons as a result of the settlement of the patent right dispute between Parsons and Clarke Chapman and Company concerning the axial flow turbine. See Clarke, 'An almost unknown great man', chronology.
30. Parsons, 'The marine steam turbine'.
31. Appleyard, *Charles Parsons*, p. 91.
32. Parsons, 'The application of the compound steam turbine'.
33. Ibid.
34. Parsons Marine Steam Turbine Company Ltd, '*TURBINIA*' brochure, pp. 5–6.
35. Ibid.
36. At a discussion of his first paper on the marine steam turbine on 8 April 1897, Parsons states as follows: 'With regard to the question of cavitation, this appears to begin – as far as my observations go (which are not nearly so elaborate as

Mr. Thornycroft's), but, so far as they go, they confirm the views which Mr. Thornycroft expressed in his paper a year or two ago – namely, that cavitation begins when the mean pressure on the blades exceeds 1¼ lbs' (Parsons, 'The application of the compound steam turbine', p. 241). As for Thornycroft's original view, see John I. Thorneycroft and W. S. Barnaby, 'Torpedo-boat destroyers', *Minutes of Proceedings of the Institution of Civil Engineers*, vol. 122 (1895), pp. 51–72.

37. See Parsons, 'The application of the compound steam turbine', appendix: Trials of the *Turbinia* (p. 237); James A. Ewing, 'Preliminary Report on Trials of the Steamer *Turbinia*', 24 April 1897, Tyne and Wear Archives Service, Newcastle-upon-Tyne.
38. For the details of the reorganization, see Parsons Marine Steam Turbine Company, Ltd, incorporated under the Companies Acts, 'For Private Circulation Only: Prospectus', 30 July 1897, Tyne and Wear Archives Service, Newcastle-upon-Tyne. Five out of six directors contributing to the first Marine Steam Turbine Company became directors/shareholders of this reorganized commercial concern. Those five directors were C. A. Parsons himself, the Earl of Rosse (brother of C. A. Parsons), Christopher J. Leyland, J. B. Simpson, and A. A. Campbell Swinton. See the above prospectus issued in 1897 and Appleyard, *Charles Parsons*, p. 91.
39. D. J. Jeremy and C. Shaw (eds), *Dictionary of Business Biography: A Biographical Dictionary of Business Leaders Active in Britain in the Period 1860–1980*, vol. 4 (London: Butterworths, 1985), p. 543.
40. Ibid.
41. For the first paid-up capital of the company, see Parsons Marine Steam Turbine Company Ltd, 'Prospectus', 1897.
42. Jeremy and Shaw, *Dictionary of Business Biography*, p. 543. The company's gross sales for fiscal 1900 are not known.
43. As for the orders for the *Cobra* and the *Viper*, see Appleyard, *Charles Parsons*, pp. 140–58.
44. And both were lost in accidents three years later (caused by factors unrelated to the performance of the turbines installed). Ibid., p. 147.
45. Appleyard, *Charles Parsons*, p. 131. Interpolation is by the author.
46. As for the Royal Corps of Naval Constructors, see K. H. W. Thomas, 'The Royal Corps of Naval Constructors: a centenary review', *Naval Architect*, September (1983), pp. 289–300.
47. A word coined by Sir George Hamilton. F. Manning, *The Life of Sir William White* (London: John Murray, 1923), p. viii.
48. C. A. Parsons and George G. Stoney, 'The steam-turbine', *Excerpt Minutes of Proceedings of the Institution of Civil Engineers*, vol. 158, Part I (1906), p. 41. Interpolations are the author's. Today the public runs of the *Turbinia* are believed to have been unofficially approved by the Navy beforehand.
49. 'Presentation of the honorary freedom of Newcastle upon Tyne to the Hon. Sir Charles Algernon Parsons', *North-East Coast Institution of Engineers and Shipbuilders*, vol. 30 (1915), pp. 582–93; Clarke, 'An almost unknown great man'.
50. Stanley V. Goodall, 'Sir Charles Parsons and the Royal Navy', *TINA*, vol. 84 (1942), pp. 1–16.
51. Ibid. Interpolation is by the author.
52. To be accurate, this characteristic of wave resistance holds good only for the range of speed that Parsons and Froude thought of at this time. At higher speeds with a Froude number of more than 0.5, there appears another summit so that wave resistance has a multiple-peak characteristic. As for the Froude number, see Chapter 2.

53. See Isamu Yoshioka, 'William Froude Den: Kindai Kogaku no Akebono, Zosengaku no Chichi' (A biography of William Froude, the founding father of shipbuilding and the dawn of modern engineering) (Tokyo: for private distribution, 1985), p. 342.
54. For a work in the Victorian social context within which various engineering work is coupled with energy physics, including thermodynamics, see Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge University Press, 1989).
55. As far as the genealogy of the development of the steam turbine is concerned, this example has also a close interconnection with the water turbine and the turbojet engine. On the connection with the water turbine, giving a counterproof of the hypothesis of 'multiple invention' formulated by Robert K. Merton, see Edward W. Constant II, 'On the diversity and coevolution of technological multiples: steam turbine and Pelton water wheels', *Social Studies of Science*, vol. 8, no. 2 (1978), pp. 183–210. On that with the turbojet engine, see *idem*, *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980).
56. On the social background of the revolution in government regarding power technology, see P. W. J. Bartrip, 'The state and the steam boiler in nineteenth century Britain', *International Review of Social History*, vol. 25, pt 1 (1980), pp. 77–105.
57. See, for example, Herbert Spencer, *Over-Legislation: An Essay* (Tokyo: Tokio Daigaku, 1878), pp. 19–53. Also see P. Abrams, *The Origin of British Sociology, 1834–1914* (Chicago: University of Chicago Press, 1968), p. 76.
58. There were subsequent public bodies in Britain that were formed to inquire about technical matters relating to the ship revolution in the second half of the nineteenth century (year within bracket indicates the year of publication of their reports): Admiralty Committee on Marine Engines (1859), Admiralty Committee on Metals (1867), Admiralty Committee on Designs (1872), Royal Commission on Technical Instruction (1884), Admiralty Committee on Boilers (1893–4).
59. Walter G. Vincenti, *What Engineers Know and How They Know it: Analytical Studies from Aeronautical History* (Baltimore: Johns Hopkins University Press, 1990), p. 236.
60. Based on ibid., table 7-1 (p. 235). Also see John M. Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (Cambridge, Mass.: MIT Press, 1985), pp. 103–20.
61. C. A. Parsons, 'Motive power', presidential address to the Birmingham and Midland Institute, *Proceedings*, 12 October (1922).
62. In his early notes on theoretical calculations for the steam turbine, Parsons incorporated a table addressing the practical problems of turbine design, such as the number of pairs of elementary turbines for a duplicate expansion based on the changing volume and velocity of steam. See Alex Richardson, *The Evolution of the Parsons Steam Turbine* (London: Offices of *Engineering*, 1911), p. 19, table IV.
63. Donald S. L. Cardwell, *Technology, Science and History* (London: Heinemann, 1972), p. 172.
64. The descriptions are based upon Iwasaki Ke Denki Kanko Kai (ed.) *Iwasaki Yanosuke Den* (A biography of Yanosuke Iwasaki), Ge Kan (Tokyo: Tokyo Daigaku Shuppan Kai, 1971), pp. 296–9. These successive entries of Japanese engineers into Mitsubishi Nagasaki Shipyard were remarkable in the climate of the time, when there were few established career patterns and recruiting qualified engineers into private enterprises had not yet become usual in Japan. On the Nagasaki Shipyard from the last days of the Shogunate to the middle of the 1880s, see Yoh Nakanishi, *Nihon Kindaika no Kiso Katei: Mitsubishi Nagasaki Zosen Sho to sono Roshi Kankei, 1855–1900* (Emergence of a modern Japanese enterprise

and its industrial relations – Mitsubishi Shipyard: 1855–1900), 3 vols (Tokyo: Tokyo Daigaku Shuppan Kai, 1982, 1983, 2003).

65. Kozo Yokoyama, 'Hakuyo mekanikaru redakushon gia ni tsuite' (On mechanical reduction gears for turbine ships), *Zosen Kyokai Kaiho*, no. 28 (1921), pp. 94–140.
66. Kozo Yokoyama, 'Zai Eikoku Kengaku Hokoku' (A report of studies in Britain), 1912 (kept by Mitsubishi Nagasaki Shipyard Archives, Nagasaki).
67. Based on Keireki Sho (Employee records), n.d., Mitsubishi Nagasaki Shipyard Archives, Nagasaki; Tokyo Daigaku, Sotsugyosei Shimei Roku (List of alumni, University of Tokyo).
68. Of course, at this stage in the development of the marine turbine, superheated steam was not yet used.
69. The descriptions are based on Mitsubishi Jukogyo Nagasaki Kenkyujo Gijutsu Hokoku (Technical report of the Nagasaki Research Institute of the Mitsubishi Heavy Industry Company), no. 15 (1966) (Mitsubishi Nagasaki Shipyard Archives), pp. 12–17. This report (henceforth Gijutsu Report) is a compilation of primary source materials including interviews with parties concerned, which was expected to provide a basis for writing the history of the Nagasaki Research Institute.
70. Gijutsu Report, no. 15, p. 16.
71. Ibid., p. 14.
72. Mitsubishi Nagasaki Zosenjo (ed.) *Shinshu no Ura Yawa* (Notes on the shipyard) (Tokyo: Mitsubishi Zosen, 1961), p.51; Gijutsu Hokoku, pp. 1–42.
73. The descriptions are based on Gijutsu Report, no. 15, pp. 18–38. From this material, it appears that the description given by Mitsubishi Nagasaki Zosenjo, Shinshu no Ura Yawa, that the analysis room had been put under the control of the engine design engineer before the organizational role of the Material Testing Laboratory within the company was first defined in 1908 is erroneous (see Gijutsu Report, no. 15, p. 13).
74. The amount of the budget allotted to the Materials Testing Laboratory is based on the *Annual Report of Mitsubishi Nagasaki Shipyard*, 1906, p. 23; 1916, p. 15. Taking into account the change in currency value during the decade based on various price indices, the expansion rate amounts to about 48–57 times. On various price indices, see Kazushi Okawa, Miyohei Shinohara and Mataji Umemura (eds), *Choki Keizai Tokei 8 Bukka* (Long-term economic statistics 8: price) (Tokyo: Toyo Keizai Shinpo Sha, 1967), statistical table 1, p. 134.
75. Kozo Yokoyama, 'Mitsubishi Juko Shashi Genko' (A manuscript of the history of the Mitsubishi Heavy Industry Ltd), n.d., p.50; Ichiro Itaka, 'Do o shuseibun to suru Cu-Al-Ni gokin no kenkyu' (Study on Cu-Al-Ni alloy), *Kikai Gakkai Shi*, vol. 25, no. 72 (1922), pp. 1–27; *idem*, 'Shin tarubin yoku zairyo gokin ni tsuite' (On new metals for turbine blades), *Zosen Kyokai Kaiho*, no. 34 (1924), pp. 83–99. Regarding copper mines in Japan, famous mines such as Ashio and Besshi had been in operation since the Edo period.
76. For a detailed discussion of the sociological implications of this effort, taking into account both the market structure and labour processes, see Miwao Matsumoto, *Fune no Kagaku Gijutsu Kakumei to Sangyo Shakai: Igirisu to Nihon no Hikaku Shakaigaku* (The scientific and technological revolution in shipbuilding and industrial societies in the age of imperialism: a comparative sociology of Britain and Japan) (Tokyo: Dobunkan, 1995), ch. 8, ch. 12.
77. A. Richardson, *The Evolution of the Parson steam Turbine*, p. 228.
78. Mikio Sumiya (ed.) *Nippon Shokugyo Kunren Hatten Shi, Jo kan: Senshin Gijutsu Dochakuka no Katei* (The history of the development of industrial training in

Japan, part 1: The process of making advanced technology take root) (Tokyo: Nihon Rodo Kyokai, 1970), p. 179. Interpolations are by the author.

79. Mitsubishi Kogyo Gakko, Mitsubishi Kogyo Gakko Ichiran (A synopsis of the Mitsubishi Industrial School), Nagasaki, May 1922, p.1. Hisaya Iwasaki was the president of the Mitsubishi Head Office which administered a number of Mitsubishi companies including Mitsubishi Nagasaki Shipyard.
80. Mitsubishi Honsha Shomubu Chosaka, *Rodosha Toriatsukaikata ni kansuru Chosa Hokokusho* (A report on how to manage workers) (Tokyo: Mitsubishi Zosen Jo, 1914), appendix, p. 39.
81. The descriptions of the Mitsubishi Industrial Preparatory School are based on Gijutsu Gakko Enkaku (The origin of the Mitsubishi Nagasaki Shipyard Technical School), mimeograph, Nagasaki, December 1968, 3 pp.; Mitsubishi Kogyo Gakko (Synopsis of the Mitsubishi Industrial School), pp. 14–15, p. 71.
82. Nihon Kagakushi Gakkai (ed.) *Nippon Kagaku Gijutsu Shi Taikei* (An outline of the history of science and technology in Japan) (Tokyo: Daiichi Hoki Shuppan, 1965), vol. 9, pp. 11–12, pp. 325–6. Also see Hiroshi Hazama, *Nihon ni okeru Roshi Kyocho no Teiryu* (The origins of industrial conciliation in Japan) (Tokyo: Waseda Daigaku Shuppan Kai, 1978). As for the contemporary educational system and qualifying examination in Japan as a general background to this situation, see Ikuo Amano, *Shiken no Shakaishi* (The social history of entrance examinations in modern Japan) (Tokyo: Tokyo Daigaku Shuppankai, 1983).
83. Estimated from Monbusho, *Sangyo Kyoiku 70 Nen Shi* (70 years of industrial education) (Tokyo: Monbusho, 1965), appendix 4: I, pp. 1001–3. Since it was prescribed that 'Apprentices' schools (*totei gakko*) are to be considered as a sort of industrial school' (Industrial School Act [Jitsugyo Gakko Rei], Imperial Ordinance [Chokurei], No. 29), the estimate here counts all apprentices' schools as industrial schools.
84. Sangyo Kunren Hakusho Henshu Iinkai (ed.) *Sangyo Kunren 100 Nen Shi: Nihon no Keizai Seicho to Sangyo Kunren* (A hundred years of industrial training: economic growth and industrial training in Japan) (Tokyo: Nihon Sangyo Kunren Kyokai, 1971), pp. 256–61.
85. Keigo Makino, 'Nagasaki-shi Mitsubishi zosenshoritsu Mitsubishi Kogyo Yobi Gakko no jokyo' (On the Mitsubishi Industrial Preparatory School at Nagasaki), *Kyoiku Koho*, no. 308 (1906), pp. 40–3.
86. *Annual Report of Mitsubishi Nagasaki Shipyard*, 1904–14.
87. The average number of graduates from the Mitsubishi Industrial Preparatory School during 1904–14 amounted to 39 in the drawing office, which averaged 63 personnel during the same period. Estimated based upon *Annual Report of the Mitsubishi Nagasaki Shipyard*, 1904–14.
88. Mitsubishi Honsha Shomubu Chosa Ka, (Report on how to manage workers), p. 62.
89. Mitsubishi Kogyo Gakko (Synopsis of Mitsubishi Industrial School), p. 62.
90. Sanshiro Okano is the first graduate as far as we know who was concerned with the design. See Yokoyama, 'Mitsubishi Juko Shashi Genko' (Manuscript history of the Mitsubishi Heavy Industry), p. 3.
91. 'Mitsubishi Zosen Shoin Hatsumei Tokkyo ni kakawaru Seiki' (The regulation on inventions and patents of employees of the Mitsubishi Shipyard). See Mitsubishi Sha-Shi Kanko Kai (ed.) *Mitsubishi Sha-Shi* (The history of the Mitsubishi Company), vol. 21: 1906–11 (Tokyo: Tokyo Daigaku Shuppan Kai, 1980), p. 953.
92. Mitsubishi Nagasaki Zosenjo, 'Shokko Katei Jotai sonota Tokei Hyo' (Statistical survey of the workers), Mitsubishi Nagasaki Zosenjo, Nagasaki, 1923, pp. 23–4.

93. See Parsons Marine Steam Turbine Company Ltd, 'Prospectus'; Mitsubishi Nagasaki Zosenjo, *Mitsubishi Nagasaki Zosenjo Shi (1)* (The history of the Mitsubishi Nagasaki Shipyard (1) (Nagasaki: Mitsubishi Nagasaki Zosenjo, 1928), p. 34. The estimated value of the capital of the Parsons Marine Steam Turbine Company is based upon the average exchange rate with London at Yokohama in 1897 (1 ¥ = 2 s. 0.4 d.), when the company was set up.
94. Alexander Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge, Mass.: Harvard University Press, 1962), p. 354.
95. In this context, the general background of Mitsubishi Zaibatsu might be relevant. See William D. Wray, *Mitsubishi and the NYK, 1870–1914: Business Strategy in the Japanese Shipping Industry* (Cambridge, Mass.: Harvard University Press, 1984), and others.
96. Hyo Hamada, 'Rateau tarubin ni kakawaru ken' (A matter concerning the Rateau turbine), 17 July 1920, Mitsubishi Nagasaki Shipyard Archives, Nagasaki.
97. There was an intermediate type called the compound turbine which combined both turbines. For the first paper on this type by C. A. Parsons, see Parsons 'The application of the compound steam turbine'.
98. Kozo Yokoyama, 'Metropolitan-Vickers Electrical Company Ltd Rateau tarubin ni kansuru Inagaki gishi no hokoku ni tsuite' (On Mr Inagaki's technical report on the Rateau turbine produced by the Metropolitan-Vickers Electrical Company Ltd), 15 July 1920, Mitsubishi Nagasaki Shipyard Archives, Nagasaki.
99. Ibid.
100. Nippon Hakuyo Kikan Gakkai Hakuyo Kikan Chosa Kenkyu Iinkai (RCMESJ) (ed.) 'Nippon Hakuyo Kikan Shi Joki Tabin Hen Soko' (An unpublished manuscript of the history of marine engineering in Japan: the steam turbine), n.d., Kaigun Hen, appended table 2.3.1. The company purchased the right of licensed production of the Zölly turbine in 1921.
101. Yokoyama, 'Metropolitan-Vickers Electrical Company Ltd Rateau tarubin', 15 July 1920.
102. Mitsubishi Zosen, *Sogyo Hyakunen no Nagasaki Zosenjo* (A centenary history of the Nagasaki Shipyard), Tokyo, 1957, appendix: the list of main products 3; RCMESJ (ed.) 'Nippon Hakuyo Kikan Shi Joki Tabin Hen Soko' (Manuscript of the history of marine engineering in Japan), Minkan Hen, appended tables.
103. Although Itaka metal was not adopted by the turbines produced at Navy arsenals due to the development by the Navy of its own new metals made around the time, it provided the first stage in the replacement of imported Monel metal by self-reliant technologies independently developed by the private sector. For the development of the Navy's own new metals for turbine blades, see RCMESJ (ed.) 'Nippon Hakuyo Kikan Shi Joki Tabin Hen Soko' (Manuscript of the history of marine engineering in Japan), Kaigun Hen, 2.2.14.
104. There is no connection here with the use of these concepts in the classical structural-functional theory in sociology which underlines the importance of functional aspects in the maintenance and change of structure of society.
105. See Mitsubishi Zosen, *Sogyo Hyakunen no Nagasaki Zosenjo* (History of the Nagasaki Shipyard), appendix: list of main products 1–7.
106. As mentioned earlier, Mitsubishi had more financial capital than the Parsons Marine Steam Turbine Company, who supplied the original marine steam turbines.
107. For the general background of Mitsubishi Zaibatsu, see Wray, *Mitsubishi and the NYK*, and others.
108. Nakanishi, *Nihon Kindaika no Kiso Katei* (Emergence of a modern Japanese enterprise), vol. 2, p. 644.

109. See, for example, Takeshi Hayashi, Tetsuro Nakaoka, Tadashi Ishii and Hoshimi Uchida, *Kindai Nihon no Gijutsu to Gijutsu Seisaku* (Technology and technology policy in modern Japan) (Tokyo: United Nations University Press, 1986), pp. 3–106; Masaaki Kobayashi, *Nihon no Kogyoka to Kangyo Haraisage* (Japanese industrialization and the transfer of the government factories to private companies) (Tokyo: Toyo Keizai Shinpo Sha, 1977), pp. 121–7, and others.
110. Accordingly, Japanese success in industrialization must be reconsidered from the viewpoint of a parallel industrialization, with private companies playing a unique and independent role in transferring, assimilating, and producing new technologies, in addition to the well-known role in implementing infrastructures already established by the governmental sector, including the military one. For a case study based upon the dual viewpoint, see Miwao Matsumoto, 'Reconsidering Japanese industrialization', *Technology and Culture*, vol. 40, no. 1 (1999), pp. 74–97. For an introductory history of technology in Japan for Western readers, see Tessa Morris-Suzuki, *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century* (Cambridge: Cambridge University Press, 1994). Technological learning in the prewar period is discussed in relation to Mitsubishi in Yukiko Fukasaku, *Technology and Industrial Development in Pre-war Japan: Mitsubishi Nagasaki Shipyard, 1884–1934* (London: Routledge, 1992). For a study on the transformation of the Fukoku Kyohei policy in Japan from 1868 to the 1990s, see Richard J. Samuels, *'Rich Nation Strong Army': National Security and the Technological Transformation of Japan* (Ithaca: Cornell University Press, 1994).

## 5 'Spin-off' in the Nationalization of R&D: The Recasting of the British System in an Industrializing Japan

1. W. H. White, 'On the establishment of an experimental tank for research work on fluid resistance and ship propulsion', *TINA*, vol. 46 (1904), pp. 39–63. (The quotation is taken from a statement by W. H. White in the appended discussion of his paper, ibid., p. 62.)
2. A supplementary note at the end of the discussion, ibid., p. 63.
3. Ibid., p. 42.
4. William Denny, 'On local education in naval architecture', *TINA*, vol. 22 (1881), pp. 144–65.
5. Ibid.
6. White, 'On the establishment of an experimental tank', pp. 41–2.
7. Ibid. Also see *National Physical Laboratory Collected Researches*, vol. 6 (1910), pp. 35–48.
8. The quotations are taken from White's statements in the appended discussion of his paper, in White, 'On the establishment of an experimental tank', p. 61.
9. Ibid., p. 40.
10. The quotation is taken from White's response to Mr. James Hamilton (Member of Council, the INA) in the appended discussion of his paper. Ibid., p. 61.
11. White's estimate given at the discussion, ibid., pp. 61–2.
12. The quotation is taken from the words of R. T. Glazebrook, the director of the NPL, in White, 'On the establishment of an experimental tank', p. 54. For the initial idea in setting up the NPL, see 'The establishment of a National Physical Laboratory', *The Electrician*, 7 October (1898), pp. 778–80.
13. White, 'On the establishment of an experimental tank', p. 54. For a brief general history of the NPL, see Edward Pyatt, *The National Physical Laboratory: A History* (Bristol: Adam Hilger, 1983).

14. White, 'On the establishment of an experimental tank', p. 62.
15. National Physical Laboratory, *Report for the Year*, 1909, p. 10.
16. The description is based on *National Physical Laboratory Collected Researches*, vol. 6 (1910), pp. 35–48.
17. The description is based on the National Physical Laboratory, *Report for the Year*, 1909, appendix 2, p. 103; *Report for the Year*, 1910, p. 88; *Report for the Year*, 1911. The first members of the committee were: Horace Darwin, FRS, Robert E. Froude, FRS, A. B. Kempe, Treasurer of the Royal Society, W. J. Luke, W. H. Maw, J. T. Milton, Lord Rayleigh, OM, FRS, W. E. Smith, CB, S. J. P. Thearle, Sir William H. White, KCB, FRS, A. F. Yarrow. See National Physical Laboratory, *Report for the Year*, 1909, p. 11, footnote.
18. In fact, the technological and industrial progress of other countries was one of the most influential factors that made Britain investigate institutional structures for promotion and utilization of science and technology on the European continent in the second half of the nineteenth century. See *Second Report of the Royal Commissioners on Technical Instruction*, vol. 1 (London, 1884), p. 540. However, the effort seems not to have stimulated effective support for such R&D as a national experimental tank. Despite Britain's original pioneering of tank experiments, R. T. Glazebrook, the director of the NPL, was obliged to visit the Berlin tank and the Paris tank, and so on, to get information on the latest design and management for the construction of the NPL tank. See *National Physical Laboratory Collected Researches*, vol. 6 (1910), pp. 39–48. For a general background of the relation of the application of physical scale modelling to engineering problems around the time when the pioneering Torquay tank was set up, see Thomas Wright, 'Scale models, similitude and dimensions: aspects of mid-nineteenth-century engineering science', *Annals of Science*, vol. 49, no. 3 (1992), pp. 233–54.
19. Kyoji Suehiro, 'Minato teishin gishi ga zosen kyokai sokai sekijo nite kokuritsu senpaku kenkyujo setsuritsu no kyumu naru o noberareshi ori no kamei no toron' (Discussion of Mr. Minato's paper proposing the establishment of a national research institute for shipbuilding, read at the general meeting of the Shipbuilding Association), *Zosen Kyokai Kaiho*, no. 48 (1921), pp. 183–6.
20. Kazuma Minato, 'Kogyoteki kenkyu kikan ni tsuite' (On an industrial research institute), *Zosen Kyokai Kaiho*, no. 48 (1921), pp. 156–80. Minato later became the director of the experimental tank run by the Ministry of Communications in 1932.
21. Ibid.
22. Rinji Zaisei Keizai Chosa Kai, Rinji Zaisei Keizai Chosa Kai Gijiroku (Minutes of *ad hoc* Investigation Committee on Finance and Economy), no. 16 (kept in National Archives Office), appended materials of 14 February 1921.
23. See Minato, 'Kogyoteki kenkyu kikan ni tsuite' (On an industrial research institute). The earliest move of the association towards the construction of the experimental tank dates back to 1906. In February of that year, Noriyoshi Akamatsu, the president of the association, submitted a proposal for construction to the government based on advice from F. P. Purvis, a British teacher employed by the Imperial University.
24. Suehiro, 'Minato teishin gishi' (Discussion of Mr Minato's paper).
25. Minato's statement at the discussion of his paper, in *Zosen Kyokai Kaiho*, no. 48 (1921), p. 182. As far as education in Japan is concerned, Suehiro's view might still have relevance today.
26. Ibid., p. 186.
27. Ibid., p. 194.

28. The Report of the *ad hoc* Investigation Committee on Finance and Economy (Rinji Zaisei Keizai Chosa Kai) Rinji Zaisei Keizai Chosa Kai Gijiroku (Minutes of) in reply to the question no. 4 'Zosengyo no Iji Hattatsu ni kansuru Konpon Hoshin Ikan' (What should be the fundamental policy for maintaining and developing the shipbuilding industry?), item 4, A-7. Collected in *Dai Ichiji Taisen Keizai Shakai Seisaku Shiryo Shu* (Collection of reprinted materials relating to economic and social policies after the First World War), vol. 1 (Tokyo: Kashiwashobo, 1987), p. 211.
29. Teishin Sho Kaiji Iinkai (Maritime Administration Committee, the Ministry of Communications), 'Kaiungyo oyobi Zosengyo no Iji Hatten ni kansuru Hosaku' (Measures to be taken for the development of shipping and shipbuilding industries), section 2, item 5 'Senpaku Kenkyu Shisetsu no Seibi' (Improvement of ship research facilities), Collection of miscellaneous public records (Kobun Zassan), vol. 34 (1922) (kept by the National Archives Office).
30. 'Senpaku Shikenjo Kinen Shi' (A commemorative publication on the history of the National Ship Experimental Tank) (Tokyo: for private distribution, 1956), pp. 6–7.
31. Mitsubishi Jukogyo Nagasaki Kenkyujo Gijutsu Hokoku (Technical report of the Nagasaki Research Institute of the Mitsubishi Heavy Industry Company), no. 33 (1968), p. 21.
32. *Zosen Kyokai Kaiho*, no. 48 (1921), p. 194. More specifically, there was also the following realization peculiar to the period after the First World War, which seems to have contributed to the 'trend': 'Hurried construction of many ships set back the net progress of shipbuilding technology in Japan.' Rinji Zaisei Keizai Chosa Kai) Rinji Zaisei Keizai Chosa Kai Gijiroku (Minutes of the Report of the *ad hoc* Investigation Committee on Finance and Economy) in reply to the question no. 4 'Zosengyo no Iji Hattatsu ni kansuru Konpon Hoshin Ikan' (What should be the fundamental policy for maintaining and developing the shipbuilding industry?), item 1, A-2 'Zosen Gijutsu' (Shipbuilding technology), 14 February 1922, p. 54. Collected in *Dai Ichiji Taisen Keizai Shakai Seisaku Shiryo Shu* (Collection of reprinted materials relating to economic and social policies), p. 203.
33. It is also possible to perceive here the increasing influence of the middle class on science and technology since the mid-eighteenth century compared with earlier period when science and technology, particularly science, tended to be a pastime mostly for the upper class (the nobility). See, for example, N. Hans, *New Trends in Education in the 18th Century* (London: Routledge & Kegan Paul, 1951), pp. 32–3.
34. For the Literary and Philosophical Society, see, for example, R. E. Schofield, *The Lunar Society of Birmingham: A Social History of Provincial Science and Industry in 18th Century England* (Oxford: Oxford University Press, 1963); N. McKendrich, 'The role of science in the industrial revolution: a study of Josiah Wedgewood as a scientist and industrial chemist', in M. Teich and R. Young (eds) *Changing Perspectives in the History of Science: Essays in Honour of J. Needham* (London: Heinemann, 1973), pp. 275–319; Arnold Thackray, 'Natural knowledge in cultural context: the Manchester model', *American Historical Review*, vol. 79, no. 3 (1974), pp. 672–709; J. B. Morrell, 'Individualism and the structure of British science in 1830', *Historical Studies in the Physical Sciences*, vol. 3 (1971), pp. 183–204. For scientific chairs created by various research institutes, see, for example, T. Martin, 'Origins of the Royal Institution', *British Journal for the History of Science*, vol. 1 (1962), pp. 49–63; M. Berman, *Social Change and Scientific Organization: The Royal Institution, 1799–1844* (Ithaca: Cornell University Press, 1978); M. L. Cooper and V. M. D. Hall, 'W. Robert Grave and the London Institution, 1841–1845', *Annals of Science*, vol. 39, no. 3 (1982), pp. 229–54. For the British Association for the Advancement

of Science, see, for example, O. J. R. Howarth, *The British Association for the Advancement of Science: A Retrospect 1831–1931* (London: British Association for the Advancement of Science, 1931); A. D. Orange, 'The British Association for the Advancement of Science: the provincial background', *Science Studies*, vol. 1 (1971), pp. 315–29; Roy MacLeod and Peter Collins (eds) *The Parliament of Science: The British Association for the Advancement of Science, 1831–1981* (Northwood, Middlesex: Science Reviews, 1981). For professional societies in a specific field, there are too many references to be given here. The Institution of Naval Architects in Britain will be considered in comparison with the Shipbuilding Association in Japan below. For an outline, see Chapter 1. For a comprehensive study of these different groups for science and technology until the mid-nineteenth century, see J. B. Morrell and A. Thackray, *Gentlemen of Science* (Oxford: Clarendon, 1981).

35. For a work on the professionalization process in England, see William J. Reader, *Professional Men: The Rise of the Professional Classes in 19th Century England* (London: Basic, 1966). For a classical general description of the process by sociologists, see, for example, Geoffrey Millerson, *The Qualifying Association: A Study in Professionalisation* (London: Routledge & Kegan Paul, 1964).
36. See Charles Babbage, *Reflections on the Decline of Science in England and on Some of its Causes* (London: B. Fellowes, 1830), p. 10; *idem, The Exposition of 1851* (London: John Murray, 1851), p. 189.
37. See Tadashi Yoshida, 'Japanese encounter with Western science', paper presented at the International Institute for Advanced Study Symposium 'Translatability of Culture', 9–11 September 1991, Kyoto. Of course, how to evaluate the revisions and transformations forms another question. It seems incontrovertible that the transfer had little impact on Japanese industrialization.
38. In general, knowledge production depends on its setting. The setting further depends on particular social backgrounds which select feasible settings. The social backgrounds include ways of life, 'definition of situation', value systems, and rules (formal or informal) which govern scientists, engineers and their communities, and their interaction with industrial society.
39. Since scientists generally lack a particular group of clients in the wider society they belong to, the process of the professionalization of science was fairly haphazard. For a standard work on the haphazard process of the professionalization of science in England, see D. S. L. Cardwell, *The Organization of Science in England* (London: Heinemann, rev. edn, 1972).
40. *TINA*, vol. 1 (1860), p. xi.
41. Zosen Kyokai Kisoku (Articles of the Shipbuilding Association), Clause 2, Clause 3. Also see *Zosen Kyokai Nenpo* (Annual Report of the Shipbuilding Association), no. 1 (1897), p. 4.
42. *TINA*, vol. 1 (1860), p. xiii.
43. Zosen Kyokai Kisoku (Annual Report of the Shipbuilding Association Articles of the Shipbuilding Association), Clause 59, Clause 61.
44. 'William Froude', *Nature*, 12 June (1879), pp. 148–50.
45. See Charles A. Parsons, 'The application of the compound steam turbine to the purpose of marine propulsion', *TINA*, vol. 38 (1897), pp. 232–42.
46. Besides civil engineers, we can even find various engineers specializing in manufacturing arms and ammunition, such as Masatoshi Okochi who became an Associate of the association in 1907 and later became the director of Physical and Chemical Research (Rikagaku Kenkyujo) in 1921. See *Zosen Kyokai Kaiho (The Journal of the Shipbuilding Association)*, no. 6 (1908), Minutes of General Meeting,

p. 2. The first president, Noriyoshi Akamatsu, was a retired Navy official and became a member of the Upper House (Kizoku In) in the same year as the association was set up.

47. 'Scheme for the Constitution of an Advisory Tank Committee and for the Working of the National Experimental Tank', National Physical Laboratory, *Report for the Year*, 1909, appendix 2, p. 103.
48. As shown in Table 5.3, the Mejiro tank came under the control of the Ship Administration Bureau of the Ministry of Communications from the outset. This control of the government organization goes back to 1916 when the Ship Equipment Testing Office (Fune Yohin Kensajo), the predecessor of the Mejiro tank, was set up. On 8 July 1916, the government department was revised by Imperial Ordinance No. 177 to set up the office under the control of the Ship Administration Bureau. It was not until the middle of wartime mobilization that the Mejiro tank became independent of the bureau in terms of its organizational standing. On 18 December 1941, ten days after the declaration of war with the US and Britain, the tank became independent of the control of the bureau and came under the direct control of the Minister of Communications.
49. After the initial problem of nationalization was solved through these measures, the national tank was transferred to governmental control as the NPL came under the control of the Privy Council for Scientific and Industrial Research in 1917.
50. The governmental sectors of the day too had little sense of 'rewards for services' offered to the private sector. According to Akio Yamagata who became the director of the Mejiro tank in 1940, even after the start of these services, fees required from the private sector were kept extraordinarily inexpensive in consideration of national policy for improving the quality of domestically produced ships. See Akio Yamagata, 'Senkei shiken 10 nen o kataru' (The 10 years history of the Mejiro tank), *Mota Shippu*, vol. 10, no. 4 (1937), pp. 268–73.
51. Although commonsense concepts are intellectually appealing and often useful to the understanding of societies, the dichotomy has little explanatory power in this context. For work calling attention to general pitfalls associated with the use of these concepts in sociology, see, for example, Steven M. Lukes, *Individualism* (Oxford: Blackwell, 1973); Hiroshi Hazama, *Igirisu no Shakai to Roshikankei: Hikaku Shakaigakuteki Kosatsu* (Industrial relations in British society: a comparative sociological consideration) (Tokyo: Nihon Rodo Kyokai, 1974), and others.
52. Generally, the form and nature of rules vary from one society to another. For example, rules tended to take a written form in modern Japan, whereas they tended to be often unwritten in Britain (for example, common law). Symbolically, it is well known that the transfer of common law to Japan failed, though not every unwritten rule is identical with common law. For this, see Rikizo Uchida, 'Kindai nihon to eibei ho' (Modern Japan and Anglo-American law), *Jurisuto*, no. 600 (1975), pp. 12–23.
53. As late as May 1901 when the Select Committee on Steamship Subsidies was set up, 'The committee preferred competition to subsidies' (Sidney Pollard and Paul Robertson, *The British Shipbuilding Industry: 1870–1914*, Cambridge, Mass.: Harvard University Press, 1979, p. 224.) It is true that 'although many aspects of British shipbuilding were unregulated, the state did to some extent help to ensure the continuing viability of the industry' (ibid., p. 229). As far as state subsidies are concerned, however, they were 'given rather shamefacedly' (ibid., p. 223). By contrast, Japan openly enacted both the shipbuilding and shipping promotion laws in 1896, the two main subsidy policies of the government for shipbuilding and

shipping industries. After the enactment, the focus of the government's financial policy for shipbuilding and shipping industries had further shifted from general to specific support such as a navigation subsidy, long-term cheap credit for shipbuilding and import duty on foreign built ships. Around the time the Mejiro tank was completed, particular stress was placed on the promotion of domestic production of high-performance ships and their protection from international competition. See Rinji Zaisei Keizai Chosa Kai, Rinji Zaisei Keizai Chosa Kai Gijiroku (Minutes of the Report of the *ad hoc* Investigation Committee on Finance and Economy) in reply to the question no. 4 (14 February 1922). Requests calling for direct and indirect protection of the shipbuilding industry still remained in Japan later on. See, for example, Junichiro Imaoka, 'Zosen shinko ni kansuru seisaku to keiei ni tsuite' ('Policy and management for the promotion of shipbuilding'), an opinion submitted to Teikoku Keizai Kaigi Kogyo Bukai (Industry Section, Imperial Economic Council) in April 1925. Collected in *Dai Ichiji Taisen Keizai Shakai Seisaku Shiryo Shu* (Collection of reprinted materials relating to economic and social policies after the First World War), vol. 5, pp. 100–7.

54. *Teishin Koho* (Gazette of the Ministry of Communications), no. 267 (21 November 1927), pp. 1341–2.
55. For the stipulation of fees for the use of the Mejiro tank, see *Senpaku Shikenjo Kinen Shi* (A commemorative publication on the history of the National Ship Experimental Tank) (Tokyo: for private distribution, 1956), pp. 81–3. It is unthinkable that in working out this prescription everyone was ignorant of the status of the NPL tank, since in the year following the completion of the NPL tank, full information on the tank had already been published in the oldest engineering journal in Japan. See Fuji Tanaka, 'Eikoku kokuritsu rigaku kenkyujo ni tsuite' ('On the National Physical Laboratory'), *Kogaku Kaishi*, vol. 354 (1912), pp. 389–443. On the financial statements of the early years of the NPL, see National Physical Laboratory, *Report for the Year*, 1901–08, Report of the Executive Committee. Also see R. Moseley, 'The origins and early years of the National Physical Laboratory: a chapter in the pre-history of British science policy', *Minerva*, vol. 16, no. 2 (1978), pp. 221–50.
56. National Physical Laboratory, *Report for the Year*, 1909, appendix 2, p. 103. Interpolation is by the author.
57. Ibid., 1910, pp. 88–92; 1911, pp. 88–90; 1912, pp. 113–15.
58. See ibid., 1912–20.
59. As far as the control of behaviour is concerned, this culture has something to do with general expectations. However, in two respects, the culture in this context is different from norm used in the sociology of science and technology. First, it concerns both individual and group behaviour, whereas norm is mainly concerned with individual behaviour. Second, its extension covers 'the interaction between the behaviours of individual scientists/engineers and their groups, and other subgroups in industrial society', whereas the extension of norm has been mainly confined to the interaction between scientists alone. 'Folkways' in sociology might fit better with the usage of culture here. See William G. Sumner, *Folkways: A Study of the Social Importance of Usages, Manners, Customs, Mores and Morals* (Boston: Ginn, 1907), ch. 1.
60. In a stricter sense, there is even a view that culture is almost impossible to transfer. See William F. Ogburn, *Social Change: With Respect to Culture and Original Nature* (New York: B. W. Huebsch, 1922), esp. p. 200ff. For an extreme standpoint claiming the strictest distinction of culture from other social forms, see Alfred Weber, 'Prinzipielles zur Kultursoziologie (Gesellschaftsprozess, Zivilisationsprozess

und Kulturbewegung)', *Archiv für Sozialwissenschaft und Sozialpolitik*, band. 47 (1920), s. 1–49. For a classical overview on the point by a sociologist, see Robert Merton, 'Civilization and culture', *Sociology and Social Research*, vol. 21 (1936), pp. 103–13.

61. Teishin Sho Kaiji Iinkai (Maritime Administration Committee), 'Kaiungyo oyobi Zosengyo no Iji Hatten nikansuru Hosaku' (Policies for the development of shipbuilding and shipping industries), section 2. Zosengyo no Iji ni kansuru Hosaku (Policies for the development of shipbuilding industry), item 5. Senpaku Kenkyu Shisetsu no Seibi (Improvement of ship research facilities), Kobun Zassan (Collection of Public Records), vol. 34 (1922).
62. Rules of the latter type tend to survive without respect to the purposes they were initially designed for. The phenomenon has been usually called reification within a more general formulation of a sociological theory. See Peter Berger and Thomas Luckmann, *The Social Construction of Reality* (New York: Anchor, 1967), and others.
63. In traditional and current usage in the social history of science and technology, 'institutionalization' in this broad sense and 'professionalization' as defined in Chapter 1 have not been conceptually distinguished, the origin of which goes back to J. D. Bernal. See, for example, J. D. Bernal, *The Social Function of Science* (London: Routledge & Kegan Paul, 1939), esp. pp. 1–15.
64. 'Triple-branching' here means that the hierarchical authority given to respective roles of every employee was defined based on three types of rules having different scopes, which produced a branching structure. 'Single-branching', on the other hand, means that the authority given to respective roles of every employee was defined based on rules of a single type, which produced a non-branching structure.
65. This point will be interpreted, together with the point made in Chapter 4, within the structure and function of the ship revolution in Chapter 6.

## 6 Conclusion: Beyond Success or Failure

1. Other foreign papers are as follows (in order of appearance in the proceedings): Mason S. Chace (US), 'Results of experimental tank tests on models of submarines'; A. Rateau (France), 'The rational application of turbines to the propulsion of warships'; O. Schlick (Germany), 'Our present knowledge of the vibration phenomena of steamers'; Frank E. Kirby (US), *et al.*, 'Shipping on the Great Lakes'; J. Johnson (Sweden), 'Recent developments in the sea transportation of Swedish ore'; O. Flamm (Germany), 'The scientific study of naval architecture in Germany'; L. A. Marbec (France), 'Notes on the collapsing of curved beams and curved elastic strips'; G. Russo (Italy), 'Fifty years of progress in shipbuilding in Italy'. See *TINA*, vol. 53, pt 2 (1911).
2. Ibid. As Kondo could not attend the congress, his paper was read by S. Nonaka, Constructor-Commander of the Imperial Japanese Navy.
3. Ibid., p. 148.
4. For a standard work by sociologists on ambivalence, see Robert K. Merton, *Sociological Ambivalence and Other Essays* (New York: Free Press, 1976). For example, in addition to the remarks quoted above, William H. White called the development of merchant shipbuilding in Japan 'a most marvellous story' and drew the attention of his audience to its rapidity by saying as follows: 'I do not know whether it has been appreciated that this mercantile fleet has been created since 1894.' (This is the year when the Sino-Japanese War started, after which the domestic production of large-scale merchant steamers began to be promoted by government policies, as described in Chapter 3. There was only one home-built

steamer of more than 1000 gross tons – the *Kosugemaru*, built at Mitsubishi Nagasaki Shipyard in 1883 – before 1894.) See *TINA*, vol. 53, pt 2 (1911), p. 147.

5. Junkichi Ishikawa, *Kokka Sodoin Shi* (History of the wartime mobilization), 13 vols (Tokyo: Kokka Sodoin Shi Kanko Kai, 1975–1987), Volume of source materials 3 (1975), pp. 412–14.
6. The descriptions are based on ibid., pp. 486–7.
7. For this, see Chikayoshi Kamatani, 'Daiichiji taisen to kogyo gijutsu no shinko saku' (The First World War and the promotion of industrial technology in Japan), *Kagaku Shi Kenkyu*, no. 15 (1981), pp. 13–28.
8. *Annual Report of the JSPS* (Nihon Gakujutsu Shinkokai Nenpo), no. 1 (1934).
9. Ibid.
10. Gakujutsu Sangyo Shinko In Setsuritsu Shuisho An (The draft prospectus of the JSPS), May 1932 (kept by the JSPS).
11. Gakujutsu Sangyo Shinko In Keikaku An (Draft prospectus of the JSPS), May 1932.
12. The descriptions are based on Gakujutsu Sangyo Shinko In no Keiei narabini Jigyo ni kansuru Setsumeisho An (Draft description of activities of the JSPS), May 1932 (kept by the JSPS).
13. See Tetsu Hiroshige, *Kagaku no Shakai Shi: Kindai Nihon no Kagaku Taisei* (The social history of science: the social institution of science in modern Japan) (Tokyo: Chuokoronsha, 1973), pp. 115–23.
14. For the notice of the Imperial Grant, see the Osata (Instruction) from the Minister of the Imperial Household to the Minister of Education on 20 August 1932 (kept by the JSPS).
15. Hiroshige, *Kagaku no Shakai Shi*, p. 123.
16. *Annual Report of the JSPS*, no. 4 (1937), p. 60.
17. See *Annual Report of the JSPS*, no. 1 (1934) – no. 12/13 (1947).
18. In the Kokusaku Kenkyu Kai Monjo kept by the University of Tokyo Library archives.
19. Ibid.
20. Ibid.
21. Ibid.
22. For this, see Shoichi Oyodo, *Miyamoto Takenosuke to Kagaku Gijutsu Gyosei* (Takenosuke Miyamoto and the Administration of Science and Technology) (Tokyo: Tokai Daigaku Shuppan Kai, 1989), based on a diary of Takenosuke Miyamoto who was deputy chief of the Agency of Planning and died just before the setting up of the Board of Technology on 24 December 1941.
23. In the Kokusaku Kenkyu Kai Monjo kept by the University of Tokyo Library archives.
24. Well before this, there were various arguments about the transfer of central government organizations to the Board of Technology. As far as we are able to confirm, based on official documents kept by Kokusaku Kenkyukai archives, there are at least three different top secret documents that prove this. See Gijutsuin Sosetsu niatari Ikan subeki Jiko ni kansuru Ken (On how to transfer the business of other ministries to the Board of Technology) (n.d.); Gijutsuin Sosetsu niatari Ikan subeki Jiko ni kansuru Oboegaki (A memorandum on how to transfer the business of other ministries to the Board of Technology) (29 May 1941); Gijutsuin Sosetsu niatari Ikan subeki Jiko (Business to be transferred to the Board of Technology from other ministries) (7 August 1941).
25. The Board of Technology controlled four extra-governmental organizations that had a close connection with the industrial sector: the Imperial Association for

Invention (Teikoku Hatsumei Kyokai), the Association for the Mobilization of Science (Kagaku Doin Kyokai), the Japanese Association for Aeronautics (Dainippon Koku Gijutsu Kyokai), and the Japanese Association of Scientific and Technological Societies (Zennihon Kagaku Gijutsu Dantai Rengokai). See Gijutsu In Gaikaku Dantai Ichiran (List of extra-governmental organizations of the Board of Technology), 20 December 1943 (kept by the Library of the Department of Economics, University of Tokyo). The last organization became famous for its contribution to the promotion of so-called Japanese quality control in the post-war period.

26. In the Kokusaku Kenkyu Kai Monjo, kept by the University of Tokyo Library archives. For the pressure from the Army and the resultant transformation of the Board of Technology, see, for example, Masakatsu Yamazaki, 'Wagakuni ni okeru dainiji sekai taisenki kagaku gijutsu doin: Inoue Tatashiro monjo ni motozuku Gijutsu In no tenkai katei' (The wartime mobilization of science and technology in Japan during the Second World War: the development of the Board of Technology based on the Inoue Tadashiro Archives), *Tokyo Kogyo Daigaku Jinbun Ronshu*, no. 20 (1995), pp. 171–82; Minoru Sawai, 'Kagakugijutsu shintaisei koso no tenkai to Gijutsu In no tanjo' (The development of the plan for science and technology renovation and the Board of Technology) *Osaka Daigaku Keizaigaku*, vol. 41, no. 2/3 (1991), pp. 367–95.
27. The statements by Yagi are based on the Report on Scientific Intelligence Survey in Japan, 1945, vol. 3 (GHQ/SCAP Records Box no. 8354 ESS (1)-00727), appendix 3-A-1. These are Yagi's words on 11 September 1945 when interrogated by General Headquarters of US Army Forces, Pacific Scientific and Technical Advisory Section.
28. The term 'trajectories' here broadly indicates the patterns of change specific to a certain area of science and technology. Apart from classical diffusion studies of technology (for example, William F. Ogburn, *The Social Effects of Aviation* (Boston: Houghton Mifflin, 1946), there are two contexts in which the term is used. One is neo-Schumpeterian innovation studies, in which the term is broadly understood as technological change with economic effects within a certain sector. The other is path-dependency studies, in which the term is more specifically understood as a stochastic process indicating the divergence of dominant technologies from optimum ones. As the description and analysis that follow will show, what the extension of the term employed here shares with prior usage is the incalculable and/or unanticipated nature of change to the eyes of the parties involved at a given time. For an example from neo-Schumpeterian innovation studies, see Giovanni Dosi, 'Sources, procedures, and microeconomic effects of innovation', *Journal of Economic Literature*, vol. 26, no. 3 (1988), pp. 1120–71. There are many other references relating to use of the term in this context, which are too numerous to list exhaustively here. For a few of these, see, for example, Richard Nelson and Sidney G. Winter, *An Evolutionary Theory of Economic Change* (Cambridge, Mass.: Harvard University Press, 1982); Christopher Freeman and L. Soete (eds) *New Explorations in the Economics of Technical Change* (London: Pinter, 1990); Nathan Rosenberg, *Exploring the Black Box: Technology, Economics, and History* (Cambridge: Cambridge University Press, 1994); Nick Von Tunzelmann, *Technology and Industrial Progress: The Foundations of Economic Growth* (Cheltenham: Edward Elgar, 1995), and others. Studies on path-dependency originate in the following two pioneering studies: Paul A. David, 'Clio and the economics of QWERTY', *American Economic Review*, vol. 75, no. 2 (1985), pp. 332–7; W. Brian Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of

Michigan Press, 1994); his original paper was published in *Economic Journal*, vol. 99, no. 394 (1989), pp. 116–31. For recent developments relating to these two research traditions, see, for example, John Ziman (ed.) *Technological Innovation as an Evolutionary Process* (Cambridge: Cambridge University Press, 2000). Studies in the history of technology which coincided with these two research traditions can be found, for example, in George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988). There are long-standing debates about the necessity of various narratives which go beyond the chronological description of technological change. For these debates, see, for example, R. Angus Buchanan, 'Theory and narrative in the history of technology', *Technology and Culture*, vol. 32 (1991), pp. 365–76; John Law, 'Theory and narrative in the history of technology: response', ibid., pp. 377–84; P. Scranton, 'Theory and narrative in the history of technology: comment', ibid., pp. 385–93. Also see Robert Fox (ed.) *Technological Change: Methods and Themes in the History of Technology* (Amsterdam: Harwood Academic, 1996).

29. C. A. Parsons, 'Improvements in the Mechanism for Propelling and Controlling Steam Vessels', Patent Record No. 394, AD 1894 (kept by Tyne and Wear Archives Service in Newcastle upon Tyne). As for the procession of events before 1884, see W. Garrett Scaife, 'Charles Parsons' experiments with rocket torpedoes: the precursors of the steam turbine', *Transactions of the Newcomen Society for the Study of the History of Engineering and Technology*, vol. 60 (1991), pp. 17–29.
30. For a brief history of steam turbine development, see H. W. Dickinson, *A Short History of the Steam Engine* (Cambridge: Cambridge University Press, 1938), chs 11–14. A standard work by D. S. L. Cardwell on the modern history of steam power and thermodynamics paid, unfortunately, virtually no attention to the advent of the steam turbine. See D. S. L. Cardwell, *From Watt to Clausius: The Rise of Thermodynamics in the Early Industrial Age* (London: Heinemann, 1971). Comprehensive analyses of the worldwide turbine development trajectory within the general context of turbojet development can be found in Edward W. Constant II, *The Origin of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980).
31. As mentioned in Chapter 3, *Kanpon* is the abbreviation of the *Kansei Honbu*, which means the Technical Headquarters of the Imperial Japanese Navy.
32. For detailed description and analysis of these dual strategies of the Navy, see M. Matsumoto, 'The Imperial Japanese Navy's connection with a marine steam turbine transfer from the West: a sociological model of the early 20th century', *Historia Scientiarum*, vol. 6, no. 3 (1997), pp. 209–27. As for a more general background of the relation between the Navy and private companies, see M. Matsumoto, 'Le jeu des rôles autour d'une turbine à vapeur', *Les Cahiers de Science & Vie*, no. 41 (Octobre, 1997), pp. 80–90.
33. The above descriptions are based on Ryutaro Shibuya, 'Kyu Kaigun Gijutsu Shiryo' (Technical documents of the Imperial Japanese Navy) (Tokyo: Association for Production Technologies, for private distribution, 1970), vol. 1, ch. 4; Shun Murata, '*Asashio* Gata Shu Tabin no Jiko (An accident of the main turbines of the *Asashio*-class)', manuscript (n.d.), p. 6.
34. Shibuya, 'Technical documents of the Imperial Japanese Navy', pp. 133–4.
35. For details of this first *Kanpon* type turbine, see Chapter 3. Also see Hakuyo Kikan Gakkai Hakuyo Kikan Chosa Kenkyu Iinkai (Research Committee of the Marine Engineering Society of Japan) (ed.) 'Nippon Hakuyo Kikan Shi Joki Tabin Hen Soko' (An unpublished manuscript of the history of marine engineering in Japan: the steam turbine), n.d., appended tables.

36. Japan Shipbuilding Society (ed.) *Showa Zosen Shi* (The history of shipbuilding in the showa period) (Tokyo: Hara Shobo, 1977), vol. 1, p. 668.
37. Michizo Sendo *et al.*, *Zokan Gijutsu no Zenbo* (A conspectus of warship construction technology) (Tokyo: Koyosha, 1952), pp. 247–9.
38. Masanori Ito, *Dai Kaigun o Omou* (On the Japanese Imperial Navy) (Tokyo: Bungei Sunju Sha, 1956), pp. 439–40.
39. War History Unit, National Defence College of the Defence Agency (ed.) *Kaigun Gunsenbi (1)* (Military equipment of the Navy, part 1) (Tokyo: Choun Shinbunsha, 1969), pp. 621–2.
40. Japan Shipbuilding Society (ed.) Showa Zosen Shi (History of Shipbuilding), vol. 1, pp. 668–9.
41. Institute for the Compilation of Historical Records relating to the Japanese Imperial Navy (ed.) *Kaigun* (The Navy), vol. 9 (Tokyo: Seibun Tosho, 1981), p. 161.
42. The *Tomozuru* incident of 11 March 1934 was the first major one in the Imperial Japanese Navy. Only a year and a half after this incident, a more serious one occurred on 26 September 1935 – the Fourth Squadron incident.
43. Based on interviews by the present author with Dr Seikan Ishigai (on 4 September 1987; 2 June 1993) and with Dr Yasuo Takeda (on 25 September 1996; 19 March 1997).
44. The purpose of this treaty was to restrict the total displacement of all types of naval vessels other than battleships and battle cruisers, while that of the Washington naval disarmament treaty of 1922 was to restrict the total displacement of battleships and battle cruisers, as mentioned in Chapter 4. This London treaty obliged the Imperial Japanese Navy to produce a new idea in hull design enabling heavy weapons to be installed within a small hull, which, however, was achieved at the expense of the strength and stability of the hull, as the incident dramatically showed.
45. Kaigun Daijin Kanbo Rinji Chosa Ka (Temporary Research Section, the Minister of the Imperial Japanese Navy's Secretariat, abbreviated to TRS hereafter) (ed.) *Teikoku Gikai Kaigun Kankei Giji Sokki Roku* (Minutes of Imperial Diet Sessions regarding Navy-related subjects), Bekkan 1, 2 (reprinted edn, Tokyo: Hara Shobo, 1984), vol. 3, pt 1, p. 86.
46. The damage due to the collision between the cruisers *Abukuma* and *Kitakami* in terms of contemporary currency is based on the above-mentioned answer by the Navy Minister Kiyotane Anbo to a question by Viscount Tanetada Tachibana made on 2 March 1931 during the 59th Imperial Diet Session. TRS, Minutes of Imperial Diet Sessions, vol. 1, pt 2, p. 831.
47. R. Shibuya, 'Jugo Zuihitsu' (Essays), sono 4 (n.d.), Shibuya archives.
48. The description of the background of the Shibuya archives is based on Shibuya Bunko Chosa Iinkai, Shibuya Bunko Mokuroku (Catalogue of the Shibuya archives), March 1995, commentary.
49. Minister of the Navy's Secretariat, Military Secret no. 266, issued on 19 January 1938.
50. Based on the *Rinkicho* Report, Top Secret no. 35, issued on 2 November 1938, appended sheets.
51. This classification assumes that if a problem at one location produces another problem at another location, the latter problem is not counted separately, but is considered as part of the former.
52. *Rinkicho* Report, Top Secret no. 35, issued on 2 November 1938.
53. *Rinkicho* Report, Top Secret no. 1, issued on 18 February 1938.

54. *Rinkicho* Report, Top Secret no. 1, issued on 18 February 1938, to *Rinkicho* Report, Top Secret no. 27, issued on 13 October 1938.
55. Shibuya, Technical documents of the Imperial Japanese Navy, vol. 1, ch. 4, p. 48.
56. *Rinkicho* Report, Top Secret no. 1, issued on 18 February 1938.
57. *Rinkicho* Report, Top Secret no. 1, issued on 18 February 1938, appended tables.
58. Junkichi Ishikawa (ed.) *Kokka Sodoin Shi* (The history of national mobilization) (Fujisawa: Kokka Sodoin Shi Kanko Kai, 1982), compiled materials, vol. 3, p. 412. The author was in charge of drafting the national mobilization plan at the Cabinet Planning Board (*Kikaku In*) in the prewar period. For the Navy, war preparation updates started from August 1940. See Sanbo Honbu (ed.) *Sugiyama Memo* (Memorand written by Sugiyama) (reprinted Tokyo: Hara Shobo, 1967), vol. 1, pp. 93–4. Sugiyama was the Chief of the General Staff of the day.
59. Records of an interview with Yoshio Kubota made by the Seisan Gijutsu Kyokai (Association for Production Technology) on 19 March 1955; Y. Kubota, '85 Nen no Kaiso' (Reminiscences of 85 years) (Tokyo: for private distribution, 1981), pp. 50–1.
60. These original remedial measures are kept in the Shibuya archives.
61. The descriptions here are based on Kaigun Kansei Honbu Dai 5 Bu, 'Rinji Kikan Chosa Iinkai Hokoku ni kansuru Shu Tabin Kaizo narabini Jikken Kenkyu ni kansuru Hokoku' (A report on the remedy and the experimental research on the main turbines in connection with the *Rinkicho* Report), Bessatsu, 1 April 1943. This is the final report of the Special Examination Committee.
62. In general, such was the standard of turbine design in the prewar period. Cf., Katsutada Sezawa, 'Vibrations of a group of turbine blades', *Zosen Kyokai Kaiho*, no. 50 (1932), pp.197–206; S. J. Pigott, 'Some special features of the SS *Queen Mary*', *Engineering*, vol. 143 (1937), pp. 387–90; 'Turbine-blade fa tigue testing', *Mechanical Engineering*, vol. 62, no. 12 (1940), pp. 919–21; S. J. Pigott, 'The engineering of highly powered ships', *Engineer*, vol. 170 (1940), pp. 410–12, and others.
63. Kaigun Kansei Honbu Dai 5 Bu, Report on the remedy, *op. cit.*
64. Engineering Lieutenant Nozaki, 'Tabin yoku no shindo ni kansuru kenkyu' (A theoretical study of turbine blade vibration), 15 January 1943. Dr Yasuo Takeda discovered this document on 3 March 1997, and it was added to the Shibuya archives.
65. Kansei Ono, 'Tabin yoku no kyosei sindo ni kansuru kinji keisan' (An approximate calculation on the forced vibration of turbine blades), Engine Laboratory, Department of Sciences, Naval Technical Research Institute, August 1943. Dr Yasuo Takeda also found this document on 3 March 1997, and it was added to the Shibuya archives. Shigeru Mori, a contemporary Navy engineer who graduated from the Department of Physics of the Imperial University of Tokyo, seems to have tried to construct a model to grasp the mechanism, whose details are not available now. See Shigeru Mori, 'Waga seishun' (My youth), *Shizuoka Newspaper*, 29 August, 30 August, 1 September (1969).
66. The directive was originally issued on 1 May 1931, the documents of which are collected in the Shibuya archives. In interpreting this circumstantial evidence, the author is indebted to Dr Ryoichiro Araki for technical advice (personal correspondence of 10 March 1999). Also see R. Araki, 'Joki tabin funko oyobi yoku no sekkei kosaku men chosa' (A survey of materials on the design and processing of the nozzles and blades of the steam turbine), report submitted to the Shibuya Bunko Chosa Iinkai (Research Committee on the Shibuya archives), 7 December 1998.
67. See W. E. Trumpler, Jr, and H. M. Owens, 'Turbine-blade vibration and strength', *Transactions of the American Society of Mechanical Engineers*, April (1955), pp. 337–41;

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68. See 'Report on *QE2* turbines', *Shipbuilding and Machinery Review*, 13 March (1969), pp. 24–5.
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70. Based on Yasuo Takeda, 'Kawaju wa *Kanpon* Shiki Tabin no Point o Doshite Toraetaka' (How did the Kawasaki Heavy Industry Ltd. assimilate the points of the *Kanpon* type turbine?), n.d.; Kawasaki Tabin Sekkei Shiryo (Kawasaki Turbine Design Materials), Dai 2 Bu (October, 1955); Letter from Yasuo Takeda, Kawasaki Heavy Industry Ltd to Kanji Toshima, IHI (n.d.). For a general description of marine turbine development in Japan, see Shigeki Sakagami, *Hakuyo Tahbin Hyakunen no Koseki* (A hundred years of marine turbine development in Japan) (Osaka: Yunion Puresu, 2002). As for the detailed description and analysis of the *Rinkicho* failure, see M. Matsumoto, 'A hidden pitfall in the path of prewar Japanese military technology', *Transactions of the Newcomen Society for the Study of the History of Engineering and Technology*, vol. 71, no. 2 (2000), pp. 305–25.
71. Shigeru Nakayama, 'Science and technology in modern Japanese development', in W. Beranek, Jr, and G. Ranis (eds) *Science, Technology and Economic Development: A Historical and Comparative Study* (New York: Praeger Publishers, 1978), pp. 202–32.
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## Abbreviations

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| JSPS | Japan Society for the Promotion of Science |
| *TINA* | *Transactions of the Institute of Naval Architects* |

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