Zeitschrift: Ferrum : Nachrichten aus der Eisenbibliothek, Stiftung der Georg Fischer AG

Herausgeber: Eisenbibliothek

Band: 93 (2024)

Artikel: Optimizing operation, reducing risk : aspects of quality and safety in the development of the steam engine

Autor: Poulopoulos, Panagiotis

DOI: https://doi.org/10.5169/seals-1061980

Optimizing operation, reducing risk

Aspects of quality and safety in the development of the steam engine

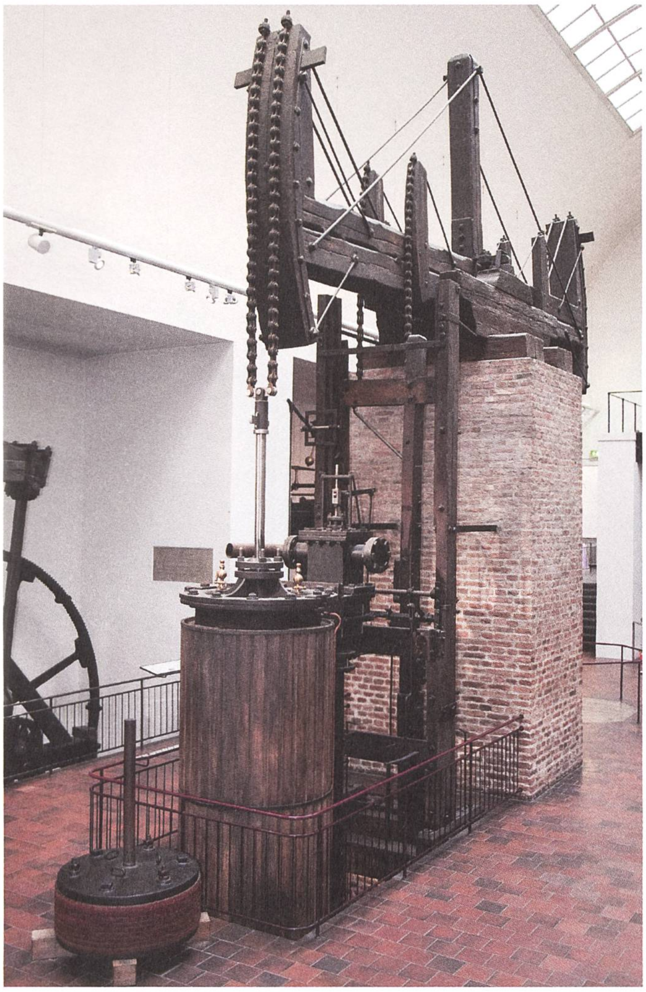
Panagiotis Poulopoulos

Arguably the most iconic symbol of industrialization, the steam engine was a driving force that revolutionized diverse sectors, from mining to printing. However, the gradual development of steam engines that were more powerful – and consequently more dangerous – also created new demands regarding quality and safety. From the late 18th century onwards, the efforts of engineers and manufacturers alike aimed, on the one hand, to enhance performance and maintenance and, on the other hand, to minimize energy losses and hazard, enabling steam engines to be used in a wide variety of applications. The history of the steam engine illustrates the constant attempts to improve efficiency, durability, and security in order to make steam a more controllable and thus marketable source of power.

If there is one single object that epitomizes the dawn of the modern world, it is arguably the steam engine. Commonly regarded as the most iconic symbol of industrialization, the steam engine was a driving force that revolutionized diverse business sectors, from mining, agriculture and transport to textile manufacturing and printing. Its widespread diffusion from the early 18th century onwards radically changed labour, society and environment, permanently transforming the natural landscape and the lives of people who built and used it.

However, the steam engine was not only a powerful instrument for industrial large-scale production, but also a platform for experimentation and innovation on various levels. For instance, many of the pioneering ideas and inventions that were applied to the design of steam engines in the decades either side of 1800 aimed to increase their reliability and efficiency, while minimizing waste and danger. This period also witnessed the introduction of new materials and methods in the construction of steam engines that were based on the concepts of rationalization, standardization, quantification, interchangeability, and miniaturization. These advances brought about new technical and procedural standards that became established in the making and operating of steam engines, as well as of numerous other mechanical devices, in the years to come.

This article examines the development of the steam engine during the late 18th and early 19th centuries from the perspectives of quality and safety.[1] The article focuses on extant artefacts in the Deutsches Museum, Munich, which houses one of the most important collections of



1 Steam engine for water pumping by William Richards, Eisleben, 1813 (Inv. No. 2337).

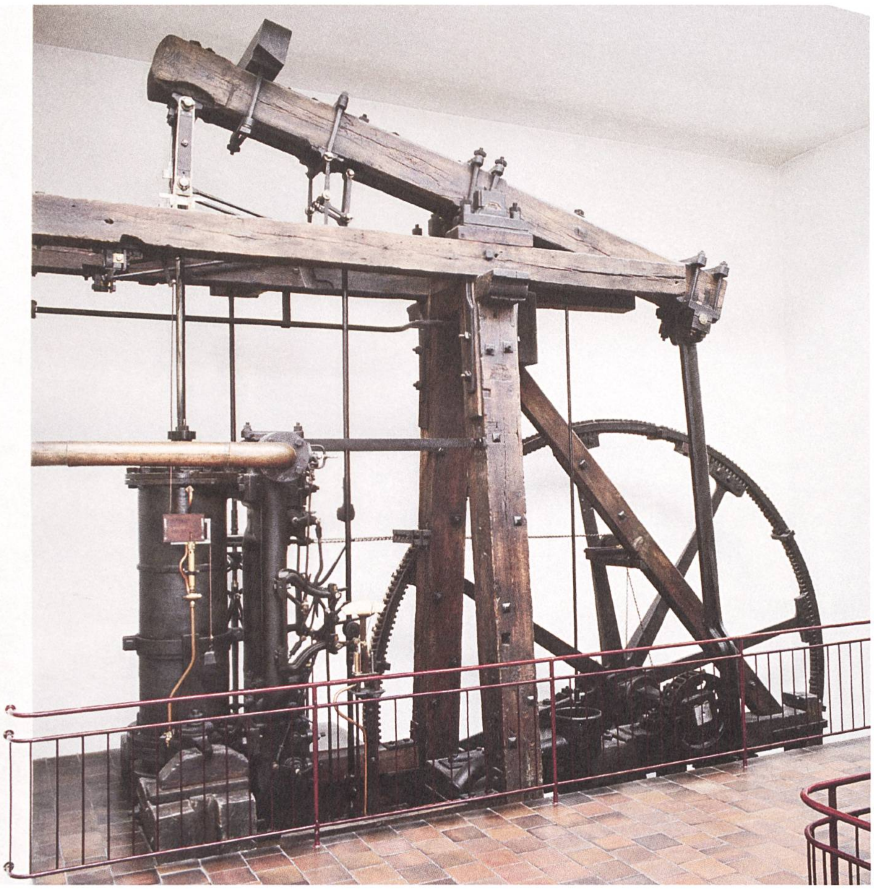
power engines worldwide, with artefacts ranging from the oldest steam engine that survives in Germany, dating from 1813,[2] to state-of-the-art engines used in modern power stations.[3] Using representative examples, the article presents and analyses several major factors in the refinement of the steam engine, while discussing how these were affected by the technological, economic and sociocultural background in which it was developed.

The steam engine was not only a powerful instrument for industrial large-scale production, but also a platform for experimentation and innovation.

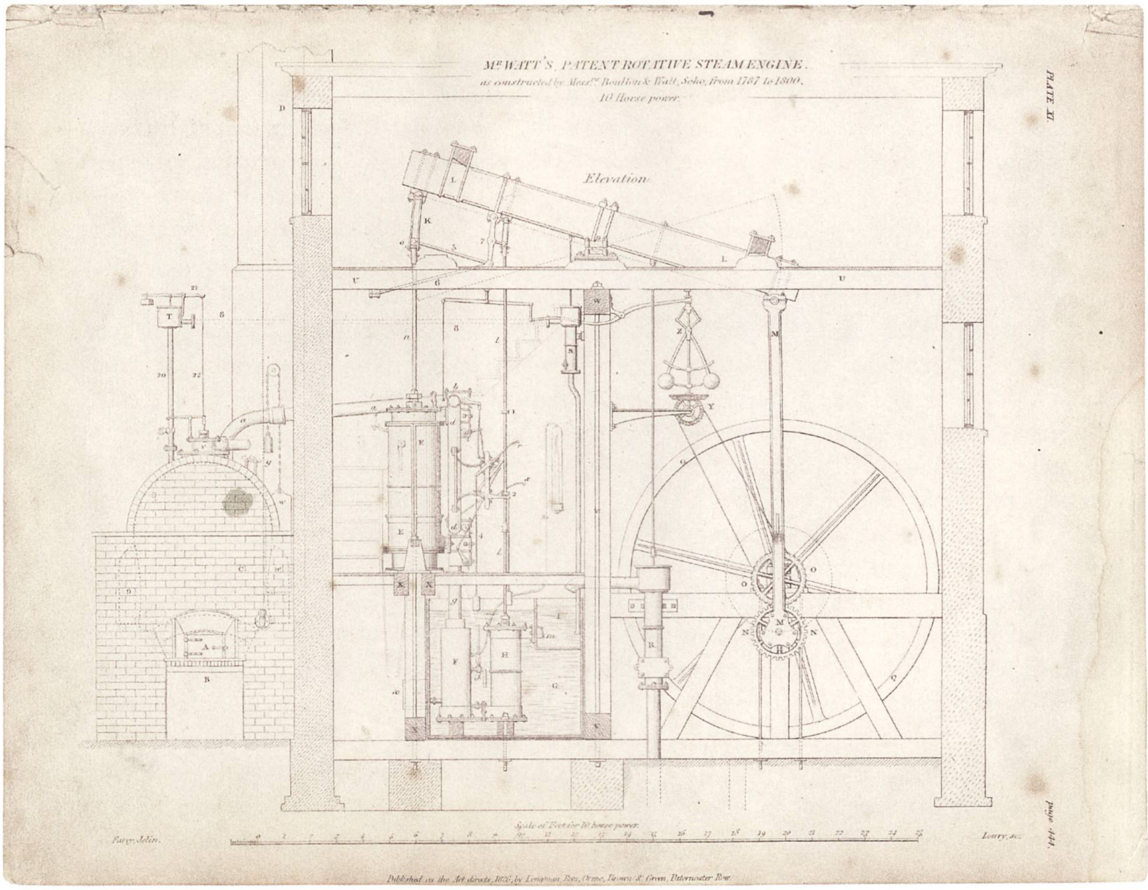
Providing durability and strength: The transition from wood to metal

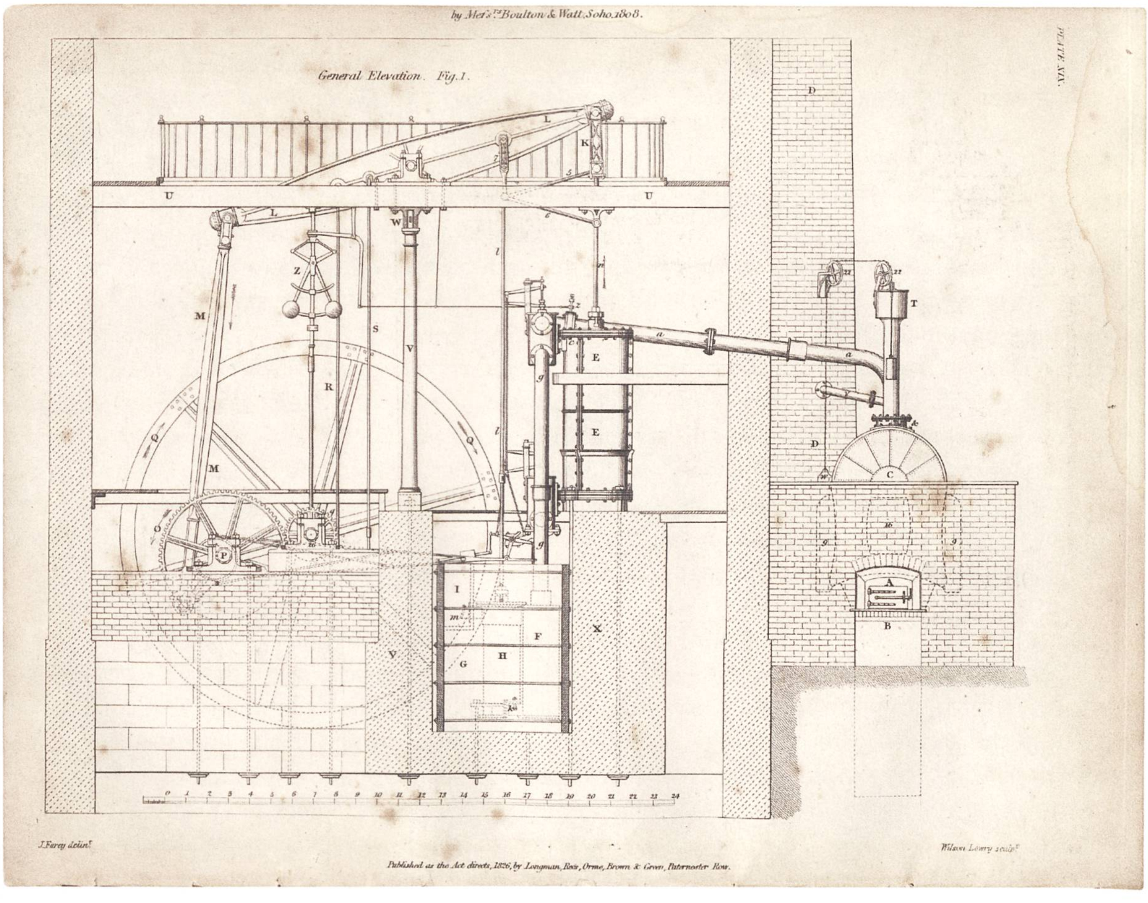
The first noteworthy feature in the transformation of the steam engine, which is also relevant in the context of quality and safety, was the transition from wood to metal for its construction. This is evidenced by the use of cast iron (and later of steel) for the working beam, supporting frame, and various functional components (such as the crank and flywheel) of the steam engine, which provided greater stability and robustness. With the introduction around 1800 of the cast-iron working beam by the firm Boulton & Watt, which replaced the earlier wooden beam on rotative steam engines, as well as with the gradual employment of metal for the supporting frame and moving parts, the steam engine became more efficient and reliable.[4]

This change in materials resulted from a combination of technical, economic and geopolitical factors. First, advances in metallurgy and casting techniques from the 18th century onwards improved the quality of metals and of the machine tools that could be used for industrial purposes.[5] Second, the wooden logs required for working beams were difficult to obtain and costly, with Matthew Boulton writing to James Watt in 1784 that "they ought to last long as its [sic] the most expensive part of the engine".[6] The shortage and high cost of timber for large beams especially during the Napoleonic Wars (1799–1815), when travel and trade were restricted, forced engineers and manufacturers to seek alternative solutions. In that historical period the demand for oak, a wood commonly used to build steam engines, grew immensely in Britain due to intensive shipbuilding for the navy.[7]



2 Top: Replica of the Boulton & Watt "Lap engine" (1788), built by the Eisenbahnausbesserungswerk, Munich, 1913 (Inv. No. 37193).
Bottom: First steam engine installed at the Krupp firm, made by the Hüttengewerkschaft Jacobi, Haniel & Huyssen (later Gutehoffnungshütte), Sterkrade, 1835 (Inv. No. 2348).





3 Top: Boulton & Watt steam engine of 10 HP, produced from about 1787 to 1800.
Bottom: Boulton & Watt steam engine of 36 HP from 1808. The two engines are depicted in John Farey, A Treatise on the Steam Engine, Historical, Practical, and Descriptive, London: Rees, Orme, Brown, and Green, 1827, plates XI and XIX, respectively. Deutsches Museum Library (Libri Rari; 3000/1900 B 384).

A third reason for switching from wood to cast iron was the demand for durable steam engines that could be exported to tropical climates in the British and other European colonies. For example, steam engines were often installed in the sugar plantations of the West Indies, where wooden parts were exposed to harmful insects and to extreme levels of humidity and temperature. A fourth significant point is that the use of metal instead of wood in the construction of steam engines met the need of fireproofing factories and textile mills, in which highly flammable materials were being worked upon; it also corresponded to the general campaign for non-combustible materials in the building and engineering sectors during the early 19th century. A comparable example of the gradual substitution of wood by metal concerns the design of windows. In Britain, initially iron and then finer metals or alloys, such as copper, bronze, and brass, were used for the window frames of houses and public buildings in the course of the 18th century. This was largely because metal window frames were fire-resistant, not prone to warping, swelling or cracking as wooden ones, and could be formed in various thicknesses, sizes and shapes, thus being safer, more durable and more functional.[8]

The replacement of timber with cast iron is apparent when comparing two emblematic rotative beam steam engines housed in the Deutsches Museum: the replica of the Boulton & Watt "Lap engine", built in 1913 but representing a typical late-18th-century design,[9] and the first steam engine installed at the Krupp firm, made in 1835. As can be observed in the images, the beam and supporting frame of the engine by Boulton & Watt are made of wood, whereas the same parts of the engine by Jacobi, Haniel & Huyssen, which was almost twice as powerful as that by Boulton & Watt, are made of cast iron.

Inevitably, the added weight due to the use of more metal components and the increase in the power of engines created new demands for stability and security. Consequently, this affected also the dynamics of the engines themselves as well as of the buildings in which they were fitted, a fact that has been largely overlooked in scholarly publications on the history of the steam engine. This development can be illustrated in the descriptions and depictions of two rotative beam steam engines by Boulton & Watt included in an early treatise on the steam engine that was published in 1827.[10]

> The use of more metal components and the increase in the power of engines created new demands for stability and security.

A comparison between the two engines shows that within 20 years the requirements in terms of statics had changed considerably. The depicted steam engine model of 10 HP, built from about 1787 to 1800, had a wooden beam and shallow foundations also made of wooden beams (usually oak), on which the various engine parts were fixed with eight bolts. In contrast, the steam engine model of 36 HP from 1808 had a cast-iron beam and much deeper masonry foundations built with brick and stone, on which 14 bolts secured the heavy engine components made with metal, such as the cylinder, air pump, supporting column, crank and flywheel. This was necessary in order to provide sturdiness and to prevent issues of distortion and damage of the engine parts due to undesirable movement, misalignment and friction.

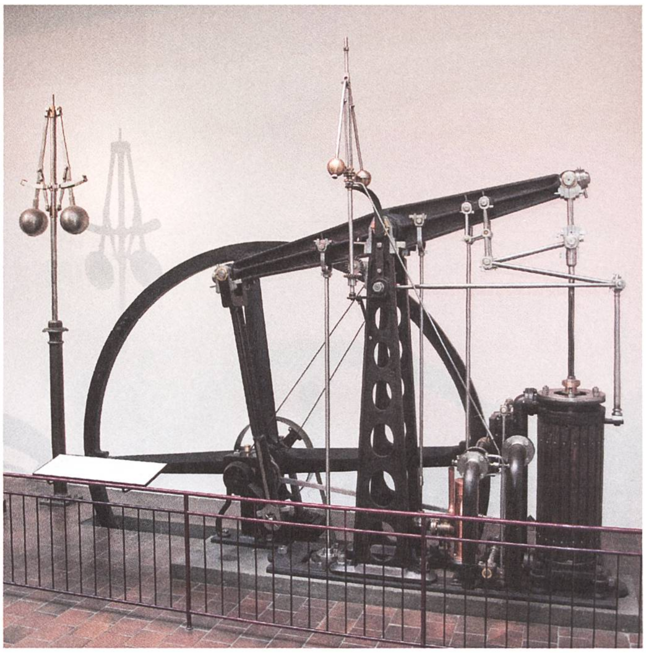
> Deficiencies in boiler design and operation occasionally led to disastrous explosions.

Under pressure: Improving and protecting the steam boiler

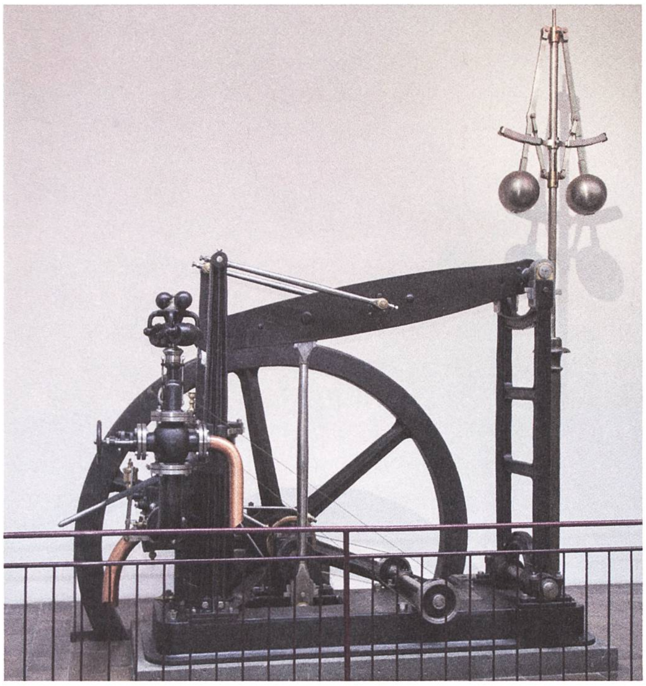
Equally important as the strengthening of the steam engine and its surroundings was the improvement and protection of the steam boiler – and accordingly the protection of the building and the staff operating the engine or other machines in it. This is obvious when juxtaposing a "wagon" boiler (so-called because of its resemblance to a roofed horse-drawn wagon) that was introduced by James Watt in the 1780s with a twin-chamber water-tube boiler developed by Ernst Alban some decades later.[11]

The wagon boiler, which was common until 1800, was typically made of wrought iron plates joined with rivets and could withstand pressure up to three bar. Since this boiler was prone to leaking, various sealing materials were employed, including lead, hemp, tar and paper.[12] As a safety measure, such boilers were usually enclosed in brickwork outside the engine room to reduce smoke and fire risk (see, for instance, the boilers in Figure 3). Contrary to the wagon boiler, the twin-chamber water-tube boiler had a more advanced design, with parts made of wrought and cast iron, joined with rivets and bolts to provide stronger and more airtight connections, and was also equipped with safety devices to prevent explosions. This was a crucial feature because such boilers were built to tolerate a maximum pressure of eight to ten bar.[13]

The gradual shift from low- to high-pressure systems during the early 19th century raised the efficiency of the steam engine, but occasionally led to disastrous explosions due to deficiencies in boiler design and operation. In order to reduce accidents and ensure the satisfactory function of steam engines, around the middle of the 19th century the first official bodies for authorized technical inspection were developed. The growing importance of systematic control is exemplified by a safety inspection manual that was issued by the Technical Monitoring Association of Munich (Technischer Überwachungs-Verein München) for the boiler of steam roller number 2285 made by the firm Maffei.[14]



4a Rotative beam steam engine by Georg Christian Freund, Berlin, 1815 (Inv. No. 12903).



4b "Grasshopper" beam steam engine built by the Este Deutsche Eisenbahnschienen-Compagnie A. G., Neuhaus bei Sonneberg, 1847 (Inv. No. 12236).

Spanning the years between 1902 and 1952, this manual records the vehicle's operating licence, regular inspections and decommissioning in 1949, with the final entry, written on the book cover, reading "25.9.1952 scrapped" ("25.9.1952 verschrottet"). The manual is thus an interesting document of the maintenance and inspection regulations for steam boilers and the work of technical monitoring associations in the early 20th century.

Size matters: The miniaturization of the steam engine

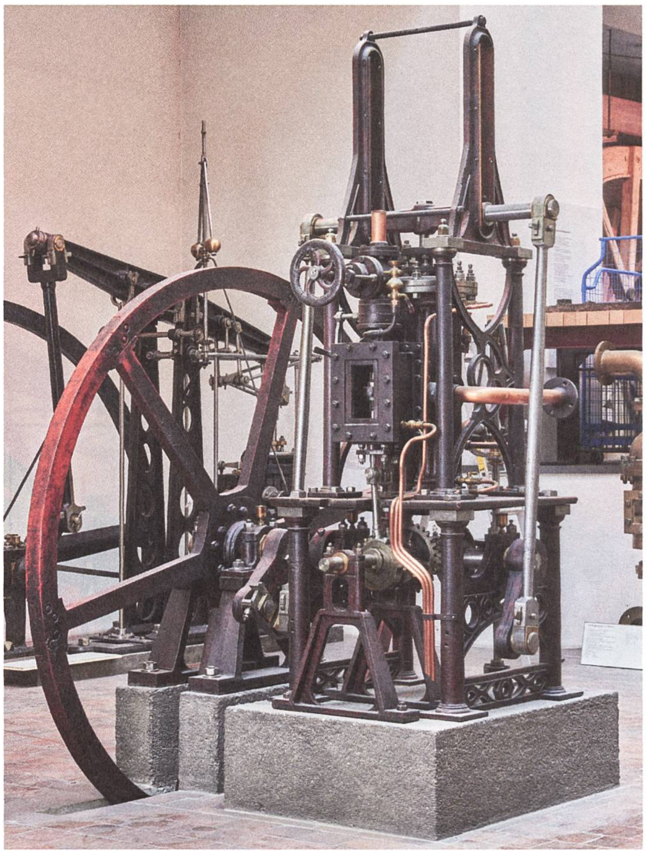
From 1800 onwards, several technological advances, some of which were described earlier, enabled the steam engine to become more powerful, and yet to have a smaller, more compact design, characterized by the reduction or abandonment of the working beam. The condensed scale provided flexibility and portability to steam engines, made their maintenance easier, and facilitated their employment in smaller workshops, as well as in agriculture and transport.

The downsizing approaches concerning the working beam can be seen on two rotative beam steam engines built three decades apart. The first, made in 1815, has a typical long beam that extends on both sides of the fulcrum at the centre,[15] whereas the so-called "grasshopper" beam steam engine, built in 1847, has a shorter working beam pivoted only on one end. Grasshopper engines were lighter than common beam engines and could be made as separate complete units, avoiding the extra construction work that was required to accommodate beam engines on-site.

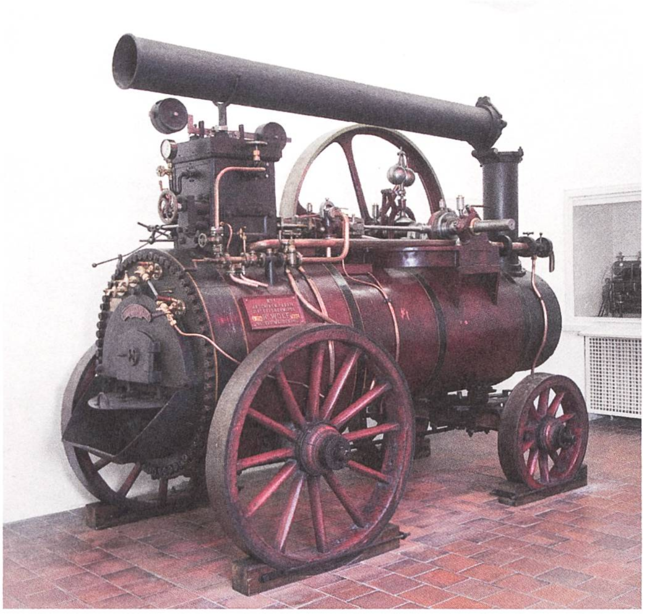
Another important step in the miniaturization of steam engines was to eliminate the working beam, consequently reducing the space and resources demanded for the engine's housing. In some cases, this was achieved by using two long connecting rods instead of the beam to transmit the motion of the piston to the flywheel. Two engines that resulted from this process were the table steam engine, invented by Henry Maudslay in 1807 and produced in the first decades of the 19th century, and the steeple engine, which was popular from around 1830 to 1860.[16]

As can be seen by the two examples from the Deutsches Museum, built c.1830 and in 1862 respectively, the main difference between the two engines is that the cylinder of the table engine rested above the crankshaft on a cast iron table that also provided support for the axis of the flywheel, whereas on the steeple steam engine the cylinder was positioned below the crankshaft, thus reducing oscillations and imbalances by uneven mass distributions.

Apart from having a compact design, both engines also offered the advantage of comprising fewer movable parts than earlier beam engines and being essentially



5 Table engine made by the Eisenwerke Kaiserslautern, Kaiserslautern, c.1830 (Inv. No. 9339).



6 Steam locomobile by Rudolf Ernst Wolf, Magdeburg-Buckau, 1862 (Inv. No. 2562).

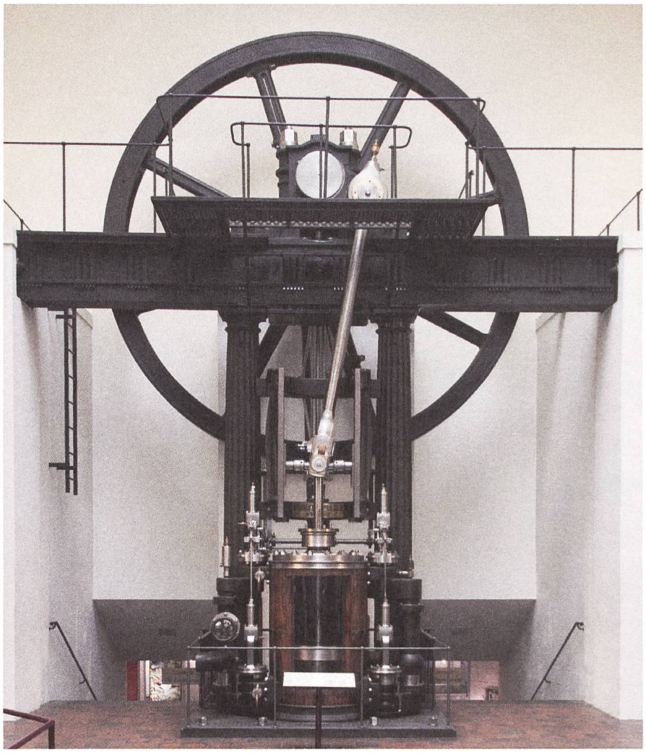
independent from the surrounding building structure. Writing about the table engine, a contemporary author argued that it is "more compact and portable, every part being fixed to, and supported by, a strong frame of cast-iron, perfectly detached from the building in which it stands: it is not, therefore, liable to be put out of order by the sinking of the foundations".[17]

> The shift from the vertical to the horizontal cylinder provided steam engines with greater accessibility for inspection and repairs.

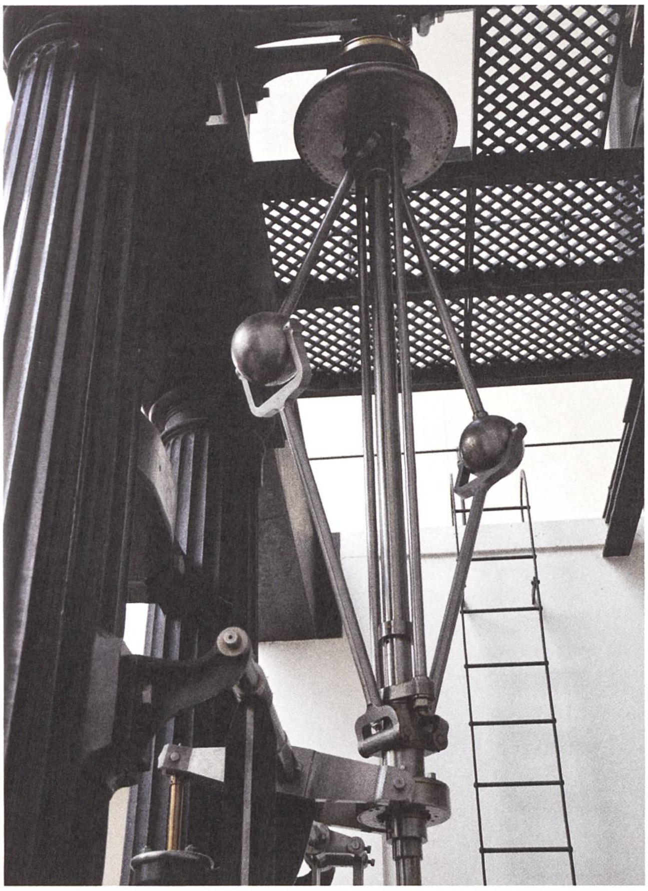
A further significant development that occurred around the middle of the 19th century was the shift from the vertical to the horizontal cylinder, which provided steam engines with greater accessibility for inspection and repairs, while requiring less headroom.[18] Finishing methods of higher quality enabled the construction of cylinders and bearings with smoother surfaces and better tolerances. This development allowed the manufacture of engines that could be integrated on carts as well as stationary engines that could be easily transported to their location. Two representative specimens from that time are a steam engine with a horizontal cylinder built in 1863 and the first travelling steam locomobile built in Germany, dating from 1862.[19]

Measures of standardization, interchangeability and automatization

A significant aspect in the upgrading of the steam engine during the early 19th century was the implementation of uniform, exchangeable parts in its construction, a concept that was also applied to the manufacture of diverse objects, ranging from clocks to musical instruments. Besides, the gradual utilization of machine-made precision screws and bolts to join and regulate metal components simplified and accelerated construction, while saving materials and time. The adoption of a modular, interchangeable design was facilitated by the use of accurate measuring devices and machine tools as well as technical drawings, templates, and three-dimensional models. This enabled firms to make consistent products, often based on tested prototypes, and allowed for repairs or adjustments, which on earlier steam engines and similar apparatuses were difficult to execute.[20]



7a First precision valve steam engine built by Gebrüder Sulzer AG, Winterthur, 1865 (Inv. No. 2346).



7b Detail of the engine's centrifugal governor controlling the precision tube valves.

The adoption of a modular, interchangeable design enabled firms to make consistent products, often based on tested prototypes.

An example of quality in terms of consistency is the Westinghouse "standard" engine, which was produced in several thousands from 1882 to 1900.[21] This engine comprised numerous standardized parts, which were relatively easy to mount together and to replace. Since the Westinghouse company issued catalogues with spare parts, the engines it produced offered increased reliability and reparability to their purchasers and users.

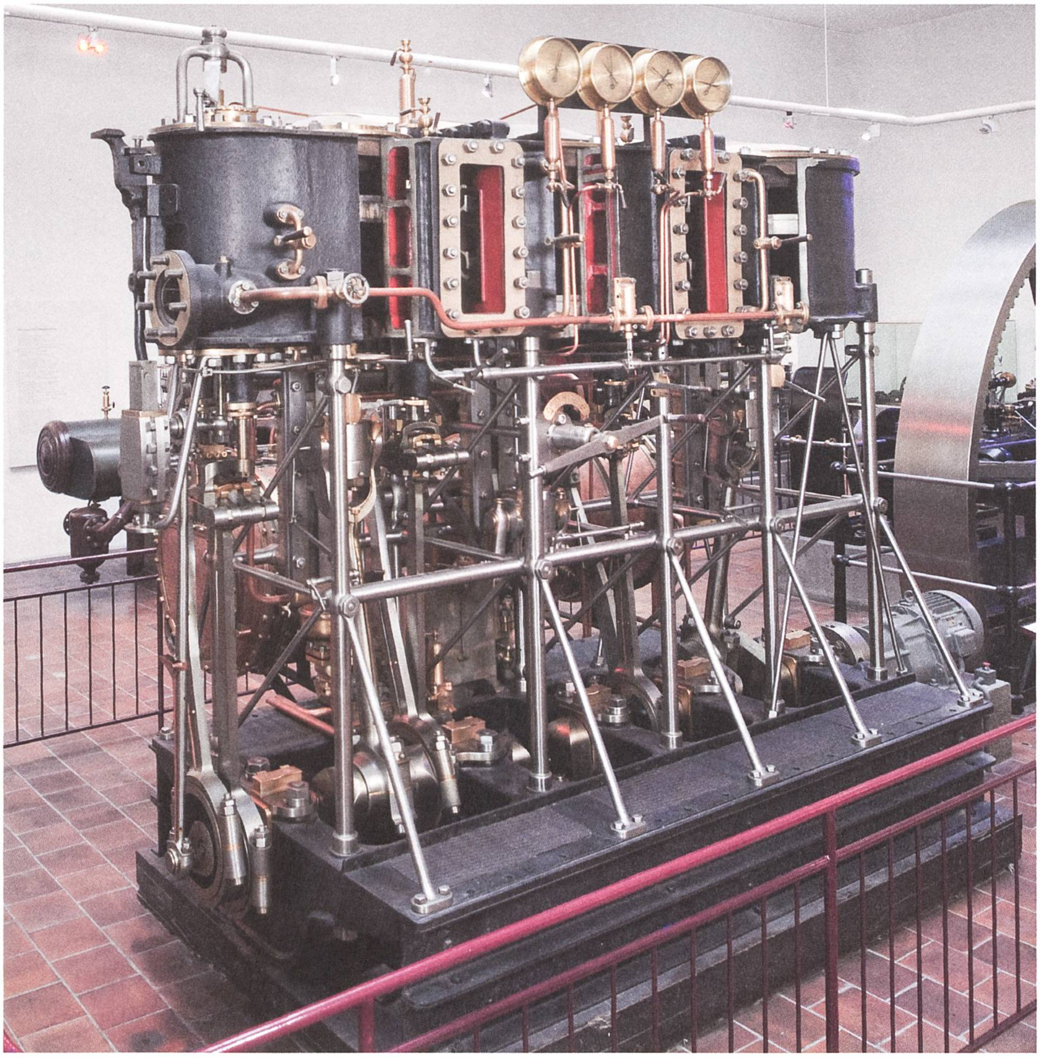
Another aspect that reflects the culture of precision, which was prevalent in the early 19th century especially in the field of scientific instruments and machine tools, regards the various contraptions to aid monitoring and control, such as the centrifugal governor or the steam indicator, that were incorporated in the design of steam engines.[22] For instance, the centrifugal governor, a rather simple but ingenious contrivance, had been originally conceived in the 17th century for the regulation of water- and windmills, but was introduced on steam engines from the late 18th century onwards to control the admission of steam into the cylinder. Later it was also employed in sophisticated control systems, as can be observed, for instance, in the first precision valve steam engine from 1865, on which a system of precision tube valves was regulated through mechanical links by the engine's centrifugal governor.[23]

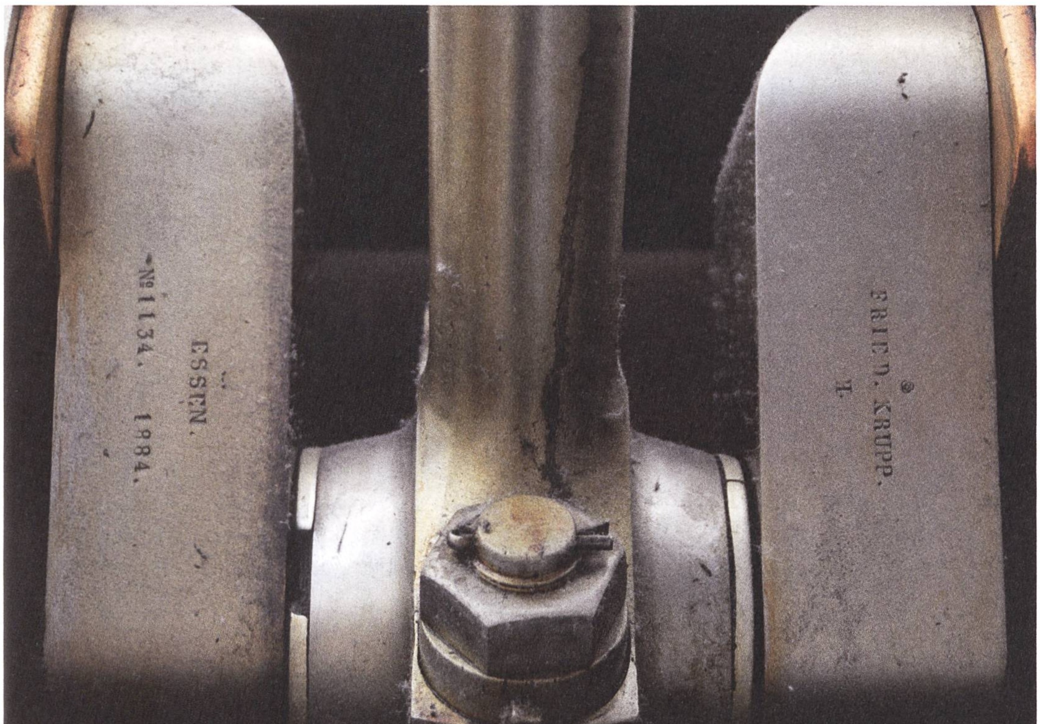
Several older technologies were adapted to the steam engine and were further developed in the 19th century.

This example shows how several older technologies were adapted to the steam engine and were further developed in the 19th century, opening up new possibilities for automatization as well as for the more effective management of safety and efficiency.

Trademarking concepts: Numbering and branding the steam engine

Steam engines made from the early 19th century onwards are characterized by the gradual proliferation of numbers, letters, and symbols applied on their metal parts. Often





8 Top: Triple-expansion marine steam engine built for the first torpedo boat "S1" by Ferdinand Schichau, Elbing, 1883 (Inv. No. 3196). Bottom: Detail of crank signed "FRIED. KRUPP. / H. / ESSEN. / No 1134. 1884."

unnoticed in scholarly literature, this fact reveals the intensive specialization of workforce, division of labour and subcontracting that was common in the manufacture of steam engines and similar machinery. The numbering and branding of standardized manufactured products, from firearms to vehicles, became essential for identification, attribution, dating, and authentication purposes. Numbered and marked components not only facilitated the assembly, after-sale service and order of replacement parts, but also helped in ensuring quality, in organizing stock and sales, as well as in preventing counterfeits and tracing stolen items.[24] The importance of trademarking as a signifier of quality can be demonstrated on a triple-expansion marine steam engine built for the first torpedo boat "S1" from 1883.[25]

The presence of a serial number and date could be important for both the producer and the client in the case of repair or replacement.

Although it was reportedly built by the firm of Ferdinand Schichau in Elbing, closer inspection of the engine shows that the parts of the three cranks were supplied by the Krupp firm, a leading manufacturer of steel based in Essen, since they are stamped "FRIED. KRUPP. / H. / ESSEN. / No 1134. 1884". These stamps, which plainly stated that Krupp, and not Schichau, was the actual manufacturer of these parts, acted as an instant advertisement of the firm's products and services, while the presence of the serial number "1134" and date "1884" could be important for both the producer and the client in the case of repair or replacement. Additionally, to avoid mistakes during assembly or maintenance, the various parts of the cranks are clearly labelled "H", "M" and "N", most likely referring to the different pressure levels the three cylinders were operating at: "Hoch" (high), "Mittel" (intermediate), and "Nieder" (low). Other parts of the engine also bear letters and numbers, apparently as a guide for their correct mounting. This is a strong contrast to earlier steam engines built before 1800, on which most parts were handmade and not standardized; these engines are usually unnumbered and bear no visible marks or inscriptions (see, for instance, the engine in Figure 1). Numbering and branding mirrors, above all, the meticulous planning and forestalling that became indispensable in the design of steam engines of increased complexity and sophistication during the course of the 19th century.

Conclusions

The various examples discussed above show that quality and safety were crucial parameters in the development of the steam engine, triggering many novel concepts and ideas. The steam engine can therefore be considered a prime example of the constant attempts to improve efficiency, durability and security in order to make steam a more controllable and thus marketable source of power. This is especially evident after 1800, when improvements in manufacturing quality helped to challenge the limits of the steam process, allowing the construction of engines that were heavier and more powerful – and consequently more complex and dangerous. The efforts of engineers and manufacturers alike aimed, on the one hand, to enhance performance and maintenance and, on the other hand, to eliminate energy losses and hazard, enabling steam engines to be used in a wide variety of applications.

Despite representing technologies and themes that are seemingly far removed from our modern everyday life, historical steam engines are fascinating objects deserving more attention, a fact often reflected by their popularity among museum visitors of all backgrounds and interests. As demonstrated by the artefacts from the collection of the Deutsches Museum presented above, steam engines are surviving witnesses of development, adaptation and change, whose study can complement the investigation of oral, written and pictorial sources, providing us with a clearer view and a better understanding of our industrial past.[26]

Being part of a current major renovation project, the new permanent exhibition on energy at the Deutsches Museum, in which most of the artefacts shown above will be presented, offers the unique opportunity to reexamine the multifaceted impact of steam engines and to display them in their broader historical, technical and cultural context, highlighting their great relevance today. After all, referring to steam engines, the objects that once shaped – and continue to influence – the world, is particularly valuable in current discussions about energy consumption, the depletion of natural resources and climate change. Indeed, in this respect, steam processes are not only considered as part of the problem, but by some, as part of the solution,[27] and within this context safety and quality assurance remain an important issue.[28] As the need to develop new technological and socioeconomic concepts that can safeguard our future on planet earth is becoming alarmingly urgent, it is important to recognize the historical role of the steam engine as a catalyst for problem solving, tinkering and innovation.

About the author

Panagiotis Poulopoulos, PhD

Panagiotis Poulopoulos holds a PhD from the University of Edinburgh and is research associate in the Department of Technology at the Deutsches Museum, Munich. He is currently working on a new permanent exhibition on energy, with a focus on steam engines. His research interests include the history of instruments of music and science as well as interactions between technology and culture. He has published numerous articles and books on diverse topics, including the conservation and display of functional artefacts; issues of material culture, provenance and authenticity; the development of museum collections; and the manufacture and marketing of instruments in the early industrial era.

Department of Technology,
Deutsches Museum, Munich, Germany
p.poulopoulos@deutsches-museum.de

Related article in the Ferrum archive:
"Das Erfinden, am Beispiel einiger Erfinderpersönlichkeiten aus dem Kraftmaschinenbau betrachtet" by Walter Traupel in Ferrum 55/1984

Annotations

1 A preliminary version of this article was presented at the 43rd History of Technology Conference of the Iron Library (TGT): "Good, Durable, Safe. Quality and Safety Requirements of Technology in History", Klostergut Paradies, Schlatt near Schaffhausen, Switzerland, 17/18 November 2023.
I would like to thank the conference organizers and scientific board for their invitation as well as the conference participants for their useful feedback and suggestions.

2 For more details of this engine, see Karl Allwang, Kraftmaschinen: Von der Muskelkraft zur Gasturbine, Munich 2012, p. 101. This catalogue provides a thorough overview of the power engines in the collection of the Deutsches Museum.

3 I am grateful to my colleague, Thomas Röber, curator of power engines, for providing information on the steam engines in the collection of the Deutsches Museum as well as for his useful remarks on an early draft of this article.

4 For more details see James Andrew, Jeremy Stein, Jennifer Tann, and Christine MacLeod, The Transition from Timber to Cast Iron Working Beams for Steam Engines: A Technological Innovation, in: Transactions of the Newcomen Society 70/1 (1998), p. 197–220.

5 See Ben Russell, The British Machine Tool Industry (1790–1825), in: Ferrum 81 (2009), p. 37–44.

6 Cited in Henry Winram Dickinson and Rhys Jenkins, James Watt and the Steam Engine (reprint of the first edition from 1927), Ashbourne 1981, p. 202.

7 On the scarcity of oak because of the needs of the expanding British navy around 1800, see Jack Vincent Thirgood, The Historical Significance of Oak, in: Oak Symposium Proceedings: 16–20 August 1971, Upper Darby, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 1971, p. 1–18, at p. 7–16. On the same topic see Patrick Melby, Insatiable Shipyards: The Impact of the Royal Navy on the World's Forests, 1200–1850 (dissertation published 2012, available at https://wou.edu/history/files/2015/08/Melby-Patrick.pdf, status 18.3.2024), p. 5–20, and Mike Baker, The English Timber Cartel in the Napoleonic Wars, in: The Mariner's Mirror 88/1 (2002), p. 79–81.

8 For more details see Hentie L. Louw, The Rise of the Metal Window during the Early Industrial Period in Britain, c.1750–1830, in: Construction History 3 (1987), p. 31–54.

9 For more details of this replica, see Allwang (n. 2), p. 100. The original engine dates from 1788 and is kept at the Science Museum, London (Inv. No. 1861-46).

10 John Farey, A Treatise on the Steam Engine, Historical, Practical, and Descriptive, London: Rees, Orme, Brown, and Green 1827, p. 444–457 and 695–708, and plates XI and XIX, respectively. A copy of this treatise survives in the Deutsches Museum Library (Libri Rari; 3000/1900 B 384).

11 For more details of these two boilers, see Allwang (n. 2), p. 119.

12 Wolfgang Noot, Vom Kofferkessel bis zum Großkraftwerk – Die Entwicklung im Kesselbau, Essen: Vulkan Verlag, 2010, p.131 f. For more details on the wagon boiler see also Conrad Matschoss, Die Entwicklung der Dampfmaschine: Eine Geschichte der ortsfesten Dampfmaschine und der Lokomobile, der Schiffsmaschine und Lokomotive, Berlin 1908, p. 596–602.

13 For more details on the water tube boiler developed by Alban, see Matschoss (n. 12), p. 612–617.

14 The earliest organization for the inspection and supervision of steam boilers was the Association for the Prevention of Steam Boiler Explosions, which was formed in Manchester, UK, in 1855 and which later became known as the Manchester Steam Users Association or MSUA; for more details see Peter W. J. Bartrip, The State and the Steam-Boiler in Nineteenth-Century Britain, in: International Review of Social History 25/1 (1980), p. 77–105. In Germany, the first association for the supervision and insurance of steam boilers was founded in Mannheim, Germany, on 6 January 1866, titled "Gesellschaft zur Ueberwachung und Versicherung von Dampfkesseln". Steam Boiler Monitoring and Inspection Associations, titled "Dampfkessel-Überwachungs- und Revisions-Vereine" (DÜV), later developed into Technical Inspection Associations (TÜV), which still exist today, with boiler inspection being an important task performed by TÜV. For more details on the early development of TÜV, see TÜV SÜD, Unsere Gründungsjahre, 1866–1900 (https://www.tuvsud.com/de-de/ueber-uns/geschichte/unsere-gruendungsjahre, status 18.3.2024). Also kept at the Deutsches Museum is an inspection manual issued by TÜV München (Inv. No. 2018-59).

15 For more details of this engine, see Allwang (n. 2), p. 102, and Matschoss (n. 12), p. 378–380.

16 In the collection of the Deutsches Museum are to be found a table engine (Inv. No. 9339) and a steeple steam engine (Inv. No. 5647). For more detail on the table and steeple engines, see Matschoss (n. 12), p. 389–396.

17 Cited in John Cantrell, Henry Maudslay, in John Cantrell and Gillian Cookson (eds), Henry Maudslay and the Pioneers of the Machine Age, Stroud 2002, p. 18–38, at p. 25 f.

18 An overview of steam engines with horizontal cylinders is included in Matschoss (n. 12), p. 404–413.

19 In the collection of the Deutsches Museum one can find both types described: a steam engine with a horizontal cylinder (Inv. No. 72918) and the first travelling steam locomobile (see image caption no. 6). For more details of these two objects, see Allwang (n. 2), p. 104 and 110, respectively. It is worth noting that locomobiles are characteristic examples of the so-called "block assembly" concept, which is still used in the design of power engines today: the steam engine was mounted on the boiler and was firmly connected to it, which made the whole installation very easy to transport and deliver to its destination. Interestingly, in Germany many TÜV centres have an old locomobile standing in front of the door, thus helping to shape the public image of steam engines. I am thankful to my colleague Thomas Röber for this information.

20 For more details see Volker Benad-Wagenhoff, Teilefertigung und Montage in der metallverarbeitenden Industrie – Entwicklungstendenzen von 1800 bis 1970, in: Ferrum 81 (2009), p. 23–36. Standardization was considerably facilitated by the gradual shift from the imperial to the metric system of measurement during the late 19th century. Nevertheless, the ways that manufacturers and users in different countries dealt with repairs or with the supply of replacement parts for steam engines, such as screws, nuts, and bolts, before the standardization of screw threads and the widespread adoption of the metric system is a topic worth further investigation. I am grateful to my colleagues Frank Dittmann, curator of electronics, and Ralf Spicker, curator of machine tools, for their valuable comments on the standardization of industrial products.

21 For more details of this engine, see Allwang (n. 2), p. 107.

22 For more details on the centrifugal governor and steam indicator developed by James Watt and his associates for the steam engine, see Dickinson and Jenkins (n. 6), p. 220–223 and 228–233, respectively.

23 For more details of this engine, see Allwang (n. 2), p. 105.

24 For more details on the importance of serial numbering and branding on manufactured goods, see Panagiotis Poulopoulos, The Erard Grecian Harp in Regency England, Woodbridge 2023, p. 51–60 and 86–93.

25 For more details of this engine, see Allwang (n. 2), p. 106.

26 The importance of material culture in the history of science and technology has been underlined in various recent publications. Indicative examples of the various approaches and challenges in dealing with artefacts of industrial heritage have been included in Klaus Staubermann, What Machine Tools Can Tell Us About Historic Skills and Knowledge, in: The International Journal for the History of Engineering & Technology, 80/1 (2010), p. 119–132; Helmuth Trischler, Festschrift: How Do We Value Artefacts in Museum Research, in: Science Museum Group Journal 13 (2020, available at https://journal.sciencemuseum.ac.uk/article/how-do-we-value-artefacts/, status 18.3.2024); and Pippi Carty-Hornsby, Preserving Skills and Knowledge in Heritage Machinery Operations, in: Science Museum Group Journal 16 (2021, available at https://journal.sciencemuseum.ac.uk/article/preserving-skills-and-knowledge-in-heritage-machinery-operations/, status 18.3.2024).

27 See, for instance, IEA, Nuclear Power in a Clean Energy System, (https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system, status 18.3.2024), or IAEA, Nuclear power and climate change: Decarbonization, (https://www.iaea.org/topics/nuclear-power-and-climate-change, status 18.3.2024).

28 See, for example, America Hernandez and Forrest Crellin, EDF ordered to inspect 200 nuclear pipe weldings after more cracks discovered, Reuters (https://www.reuters.com/business/energy/edf-ordered-inspect-200-nuclear-pipe-weldings-after-more-cracks-discovered-2023-03-10/, status 18.3.2024).

Image Credits

1-6 © Deutsches Museum.

7a © Deutsches Museum.

7b © P. Poulopoulos.

8 Top © Deutsches Museum; bottom © P. Poulopoulos.

EISENBIBLIOTHEK

Reiseberichte eines Pioniers

Johann Conrad Fischer als Zeuge der Industriellen Revolution

Digitale Edition der Reisetagebücher von
Johann Conrad Fischer 1794–1851

«Glücklicherweise hatte ich mein Schreibgerät bei mir, und zu noch grösserem Glück fand ich vortrefflichen Ale, besser noch als in keiner Stadt.»
(Sheffield, 1. Juli 1825)

Tauchen Sie ein in die Anfangszeit der Moderne und reisen Sie mit Johann Conrad Fischer (1773–1854) zu den Schauplätzen der Industriellen Revolution. Die digitale Edition von Fischers Reisetagebüchern enthält interaktive Reiseitinerare und ein Register mit 2400 Personen, Orten, Ereignissen und Begriffen. Rund 900 Bilder geben Einblick in den Alltag, die Industrie, das Reisen und das gesellschaftliche Leben zu Fischers Zeiten.

www.johannconradfischer.com